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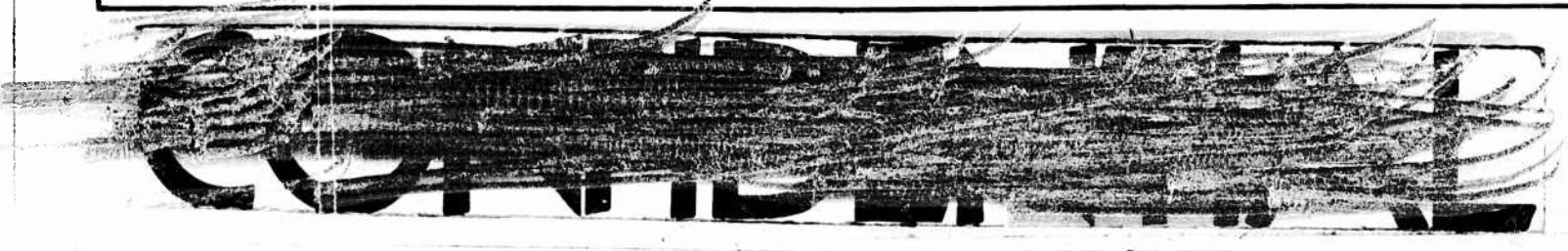

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Guided Missile Personnel Research: Report No. 4

A COMPARATIVE ANALYSIS OF MISSILEMAN TASKS FOR FIVE GUIDED MISSILES

Volume 1. Methodology and Results

Prepared under the Sponsorship of the

BUREAU OF NAVAL PERSONNEL

Robert Glaser

Jack Hahn

John C. Phillips

Wesley M. Rohrer, Jr.

George E. Jones

AMERICAN INSTITUTE for RESEARCH

PITTSBURGH, PENN

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B U R E A U O F N A V A L P E R S O N N E L

Technical Bulletin

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Volume 1

Robert Glaser, Project Director
Jack Hahn
John C. Phillips
Wesley M. Rohrer, Jr.
George E. Jones

American Institute for Research
Pittsburgh, Pennsylvania

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ABSTRACT

This report presents a detailed analysis of the skills and knowledges required by guided missilemen for the performance of tasks associated with particular guided missiles and groups of missiles. This material should provide the basic data for the development and refinement of: a rating structure, rating qualification examinations, selection procedures, training programs, and proficiency measurement procedures.

Chapter 1 describes the procedures and methodology by which the behaviors involved in guided missile tasks can be specified and integrated for a number of guided missile systems. These procedures require (1) that the tasks performed for all missiles be analyzed in terms of their component behaviors and (2) that the equipments involved in these tasks be analyzed into their component parts. The units of analysis are then compared in order to determine those aspects common to several missiles and those aspects unique to particular missiles.

Chapter 2 presents the results obtained from the application of these procedures. This chapter presents a comparative analysis of the skills and knowledges required for the operation and maintenance of five guided missiles with respect to the duties of guided missileman ratings. Three sections comprise this chapter, namely, Testing and Adjustment Procedures; Trouble Shooting; and Handling, Assembly and Servicing. For each of these sections analyses of the tasks behaviors of the guided missileman are presented for Terrier, Regulus, Sparrow I, Petrel and Dove. An over-all analysis of general underlying behaviors required for the maintenance of these missiles is given in terms of the following:

1. The categories of behavior required for the performance of testing and adjustment procedures that are common to the missiles studied and that are unique to particular missiles.

2. The kinds of trouble-shooting behavior required by the five missiles in terms of the number of component equipment chassis requiring particular kinds of trouble-shooting procedures.

3. The elements of knowledge of missile functioning common to the missile studied and the elements of knowledge unique to particular missiles.

4. The categories of behavior required for the performance of handling, assembly and servicing activities that are common to the missiles studied.

The report also discusses important problems for future research and includes appendices which present detailed equipment and behavioral analyses.

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C O N T E N T S

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CHAPTER 1

PROBLEM AND PROCEDURE

With the rapid development of guided missiles of many different types, it is necessary to determine the maximally effective use of manpower with respect to these different kinds of complex equipments. Objective personnel data must be obtained for each missile and this information must be integrated to provide both over-all and specific information which can be employed in the establishment of manpower policies and procedures. In order to accomplish this the Personnel Analysis Division of the Bureau of Naval Personnel requested a horizontal or comparative analysis of the personnel aspects of five representative guided missiles. The accomplishment of this objective required (1) the detailed analysis of the skills and knowledges involved in the performance of job duties required for each particular missile and (2) a comparative analysis of the skills and knowledges involved in all five missiles. This volume presents this comparative analysis of job behaviors and describes the procedures developed to accomplish it. The specific purpose of the volume is to provide a sourcebook which can be used as a factual reference for the development and refinement of such manpower procedures as the following: (a) rate qualifications and rating structure, (b) personnel selection procedures, (c) basic and advanced training curricula, (d) proficiency measures and standards of job proficiency, and (e) the assignment of personnel to guided missile duties.

The collection and compilation of task information for newly developed guided missiles presents some special problems. These problems and the procedures developed to collect and compile task

information are described in a previous technical bulletin.[1] These procedures were utilized by the Personnel Research Field Activities of the Personnel Analysis Division - BuPers and the American Institute for Research to collect and compile the basic data upon which the comparative analysis presented in this report is based. These data consisted of operational and maintenance manuals, manufacturer's reports and specifications, training outlines, and detailed task analysis catalogs; these catalogs were developed on the basis of field job analysis, interviews with naval personnel and civilian design and manufacturing engineers, and study of operation and maintenance manuals. The completeness and comprehensiveness of these materials varied with the developmental progress of the missile concerned; this will be specified as the tasks involved in the operation and maintenance of each missile analyzed.

It should be stated here that this report refers, in particular, to the duties of the guided missileman, the GS and GF ratings; other ratings are, of course, involved in the course of guided missile duties from storage depot to launching. Previous study[2] of the duties required for the operation and maintenance of guided missiles has indicated that it is most logical to assign to the guided missileman the responsibility for the missile or "bird" proper including its internal electronic and hydraulic components; along with this comes the responsibility for operating and maintaining associated missile testing, servicing and handling equipment. Activities

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[1] Glaser, R; Hahn, J.; and Phillips, J.C. "Collecting and Compiling Task Information for Newly Developed Guided Missiles." Bureau of Naval Personnel Technical Bulletin 53-2, American Institute for Research, August 1953.

[2] Glaser, R.; Talbert, G.E.; and Carlucci, C.A. Guided Missile Personnel Research: Report No. 1, American Institute for Research, June 1952.

concerned with the operation and maintenance of external guidance and fire control equipment, launchers and associated hoists, propulsive systems such as JATO units and jet engines, and standard airplane components are most logically assigned (and in most situations it is administratively feasible to do so) to existing ratings concerned with such equipment. An exception to this general division of duties may be required for submarine personnel where it may be necessary for a guided missileman to know both missile internal guidance systems and the associated external guidance equipment, e.g., in Regulus bi-polar guidance. It should be emphasized that this report is not concerned with all the duties required for the operation and maintenance of guided missiles, but only with those duties that have been assigned to or are logically considered to be the duties of the guided missileman ratings; this includes the external guidance duties which may be assigned to submarine personnel.

The Problem

The general problem involved in performing a comparative analysis of the behaviors involved in the operation and maintenance of several complex equipments is to develop a method for describing, classifying and comparing behaviors. Meaningful categories of behaviors need to be derived which reduce the description of the multitude of behaviors performed into a workable set of categories and which can specify those behaviors that are common to two or more missiles and those behaviors which are unique to a particular missile. The word "meaningful" as used here is used with reference to utility, that is - Can the behavioral categories be employed as a factual basis for the development of rating structures, qualification examinations, training curricula, and proficiency examinations for Navy guided missilemen? The general problem can be divided into two sub- problems:

1. How can the multitude of behaviors required for the operation and maintenance of a complex missile be best described in succinct and meaningful (in the sense explained above) units?

2. How can these descriptive units once developed best be compared to yield a meaningful comparative analysis of the behaviors involved in several complex equipments?

These two problems are certainly not mutually exclusive; the successful accomplishment of (1) facilitates the accomplishment of (2). However, for analysis of the over-all problem, they can be considered separately.

Conventional job analysis procedures offer little direct help by way of definitive procedures which can be applied to solve these problems. With reference to the first problem, i.e., how can the behaviors required in operations and maintenance activities be best described in succinct and meaningful units?--the initial attempts by the present project to answer this question indicated that, with the large variety of behaviors involved, one general descriptive scheme covering all kinds and levels of behavior would not yield the most clear-cut results. Different kinds of behavior and behavior at different levels of complexity required different descriptive approaches. The kinds or levels of behavior involved in the job of the guided missilemen can be divided generally into three groupings: (1) Testing and Adjustment, (2) Trouble Shooting and (3) Handling, Assembly and Servicing. Testing and adjustment activities include the routine performance of testing, checking, alignment and adjustment procedures, the use of programmed go-no-go test equipment and unprogrammed test consoles, and the replacement of defective units and components. Trouble shooting refers to performance of procedures for the interpretation of trouble symptoms and for the isolation of a defective component or unit in a missile and its associated

equipment. Handling, assembly and servicing includes the procedures performed and facility with the tools and equipment used in the transfer and mating of missile sections, and in missile servicing, i.e., charging and bleeding of missile hydraulic and pneumatic systems. -- The development of procedures for analyzing and comparing behaviors will be discussed for each of these groupings.

Testing and Adjustment

Considerations

The considerations involved in analyzing and describing the behavior involved in the performance of testing and adjustment procedures are as follows:

1. This kind of behavior, for the most part, is relatively structured, that is, the behaviors that make up a testing and/or adjustment task constitute a step-by-step sequence that in many instances comprise standing operating procedures. The steps involved or combinations of these steps may indicate units of description.

2. The procedures involved consist of behaviors that range from those that require a minimum of electronic (and hydraulic) knowledge to those that require detailed training in the use of complex equipment and in making the interpretations required in the use of this equipment.

3. The minimum training—detailed training continuum implied in (2) above is necessitated because the behaviors involved consist of several categories of sub-behaviors, namely, manipulative behavior, precautionary behavior (precautionary practices), and decision-making behavior (interpretations). The amount of training and background knowledge required to perform a procedure is a function of its position along the following continuum:

simple manipulation	complex manipulation	simple and/or complex manipulation plus precautionary behavior	simple and/or complex manipulation plus precautionary behavior plus decision-making

4. Adequate and useful descriptions of behavior (for training and proficiency measurement purposes) should indicate in one description the manipulative behavior involved, i.e., "what is done," and the precautions and interpretations involved. "What is done" can be described through the use of consistently used verbs; words like "connect", "adjust", "set up" can be used with consistent reference to certain manipulative behaviors. The most concise way to indicate precautions and interpretations is to state the equipment being used or worked on and, where necessary, to state what is being accomplished with this equipment. This implies to instructors and proficiency test writers, who are familiary with this equipment, the precautions and interpretations necessary in using the equipment to accomplish a particular job. For example, the statement "making connections" can imply certain manipulations if the word "connecting" is generally defined; however, "making microwave connections" makes the statement more denotative of the actual job and also implies the precautions and refinements involved when using microwave guides. Again, the statement "set up and use a synchroscope" implies certain behaviors; however, the statement "set up and use a synchroscope to measure signal to noise ratio" implies more explicit interpretations involved in the performance of the job. For specifying detailed curriculum exercises, for designing training aids, and for the actual detailed preparation of proficiency measures, the precautions and interpretations might be listed. However, for the present purpose such a degree of detail would be unnecessary and cumbersome.

5. Another aspect in describing the behaviors that make up a task and its component procedures is consideration of the level of

generality or specificity that is to be employed in the descriptive behavior statements. This is a difficult problem. On the one hand behavior can be described in terms of such specificity as "Twist, clockwise or counter-clockwise as required, R-5618 on the 150 volt regulator on chassis PP-185 and observe the voltmeter on the front panel of PP-185 until the pointer is ± 2 divisions of the desired reading". On the other hand general statements can be written, such as "Adjust and repair radar equipment". The level of generality-specificity at which descriptions of behavior should be written for particular purposes is difficult to determine and difficult to maintain consistently in the course of describing a large number of varied behaviors. At either of the two extremes described above, behaviors that require different training contexts may sound quite similar. In the present study, for the purposes of indicating rating qualifications and training requirements, it seemed desirable to employ a descriptive level between these two extremes which would result in descriptive categories which were neither too specific nor too general to be put to use by rating qualification, curriculum and test development agencies. Nevertheless, the problem of the level of behavior description required for particular uses and how this level is determined is still an important problem for future research.

Procedure

With the above considerations in mind with respect to testing and adjustment procedures the following method was adopted for the description and categorization of the behaviors involved:

STEP A. For each missile, testing and adjustment activities were classified into tasks. A "task" was defined as a particular work mission specified by established operating procedures and by maintenance manuals; such tasks were labelled, for example, "Servo Test Console Maintenance Check" or "Missile Control System Operational

Check - Using a Programmed Console". In order to provide a standard set of terms by which to classify and label tasks the following definitions were developed:

Operational check - An operational check is a test of equipment to indicate either operational readiness or some out-of-tolerance condition; if the latter occurs a maintenance check follows.

Maintenance check - A maintenance check is a test of equipment to narrow the location of a malfunction or out-of-tolerance condition; such a check may include accompanying alignment, adjustment, simple trouble shooting and simple repair. Simple trouble shooting as defined here can include the use of standard instruments in the course of following routinely specified or checklist procedures. This level of trouble shooting ordinarily involves resistance, voltage and continuity checks; tube testing and replacement; and visual inspection of electro-mechanical devices, e.g., relays and synchronous timers.

Test console - A test console consists of a group of standard test equipment and/or special circuitry and associated power supplies that are required for the maintenance of a particular equipment.

Test set - A test set consists of one piece of portable test equipment, usually not standard and usually simpler than a test console.

Programmed - The word "programmed" refers to a test console that is "completely" automatic. The operator makes connections between a missile and the test console or test set; he then makes a minimum of front panel adjustments and initiates the test with a switch or push button. Go-no-go indications of missile functioning are given by lights or simple meters.

Semi-programmed - When using a semi-programmed test console or test set, the operator connects a missile to the test equipment

and performs simple manual procedures to carry out a test. He reads indicator lights or simple meters which give go-no-go indications or other indications of missile functioning.

Non-programmed - When using a non-programmed test console or test set, the operator connects a missile to the console or test set and performs a series of manual procedures often according to a specified schedule. He reads and interprets meters, scopes and other indications to determine missile functioning.

Employing these definitions the tasks involved in testing and adjustment activities for each missile were named. A task name consists of the following:

1. The type and/or name of the equipment or component being tested.
2. Specifications as to whether the procedures involved comprise an operational or maintenance check.
3. If an operational check is involved the task name states whether a programmed, semi-programmed or non-programmed console is used in making the check and the name of the particular console. If a maintenance check is involved the kind of console used is not stated because it is generally true for the equipment involved here that most maintenance checks involve unprogrammed consoles and/or the use of standard test equipment.

Some examples of task names used in this report are "Missile Control System Operational Check - Using a Programmed Console (BuOrd Functional Test Equipment)", "Pulse Code Chassis (Radar Beam Simulator) Maintenance Check", and "Test Console (Receiver Test Panel) Maintenance Check". The testing and adjustment activities for each of the missiles studied in this report were classified into a set of component tasks. The tasks for each missile are listed in Appendix B.

STEP B. Each task was analyzed into a series of descriptive behavior statements. These behavior statements consist of two parts:

(1) the manipulations performed expressed in terms of consistently used verbs, and (2) the equipment worked with, and where necessary, specification of what is being accomplished with this equipment. Consisting of these two parts a behavior statement describes the observed manipulations performed and implies the precautions and interpretations involved in testing and adjustment procedures. These behavior statements formed the descriptive units by which testing and adjustment activities for the different missiles were compared. An example of a task and its associated behavior statements is given below (the example is a Terrier missile task); to distinguish the two parts of a behavior statement, the words and phrases describing the "manipulations performed" are underlined:

Test Console (Monitoring Panel) Maintenance Check

1. Set controls and warm up test console. Throw switches in sequence to initial positions and adjust potentiometer control knobs in sequence to specified dial or indicator setting.
2. Make necessary electric cable connections from test console to power sources.
3. Use a standard stopwatch to calibrate an elapsed time meter.
4. Set switches and potentiometer control knobs to specified settings. Install jumpers between cable plug pins. Observe multimeter readings, built-in meter, and lamp indications to check performance of test console.
5. Set up and use a standard built-in oscilloscope to monitor ac and dc steady state signals.
6. Set up and use a standard oscilloscope to determine the phase angle between two af signals.

6a. Interpret Lissajous figures as viewed on an oscilloscope screen in terms of phase angle between two signals.

7. Set up and use a dual-beam oscilloscope or a standard oscilloscope with an electronic switch to determine the phase angle between two af signals.

7a. Compute phase angle between two signals from measurements of the displacement of the signal peaks.

8. Set up and use a Graham variable speed drive to drive a potentiometer and/or a servo generator at specified speeds of rotation.

9. Set up and use a standard built-in pen recording oscillograph for monitoring ac and dc signals.

After all source materials were carefully checked to insure that all tasks for which adequate information was available had been analyzed, 771 behavior statements describing 98 tasks had been written for the five missiles under consideration. This analysis is presented in Appendix B .

STEP C. All the testing and adjustment behavior statements for all missiles were then classified into categories of similar behaviors. This was accomplished according to the following procedure:

1. All behavior statements were put on individual cards.

2. A group of two engineers and two personnel psychologists who had studied the five missiles were asked to sort the cards into similar piles or categories. Similarity was defined in terms of two criteria questions which the group of judges was asked to keep in mind, namely,

   a. In the performance of the behavior does a man use the same kind of tools and equipment?, and

   b. Does the behavior require relatively simple go-no-go judgments or are more complex interpretations involved?

These two criteria appeared to establish an adequate basis for the classification of behaviors into meaningful job-categories. More numerous and complex criteria tended to make judgments less reliable by giving the judges too much to keep in mind; and these criteria could usually be subsumed under one of the two criteria adopted.

3. The five missiles were taken one at a time and the behavior statements of the first missile were sorted into categories; these categories were then combined, extended and new categories developed

as the behavior statements for the next and following missiles were classified. Classification into a particular category was made by group consensus; if two judges disagreed the statement was discussed and, if necessary, original source material was checked to resolve the disagreement.

By this relatively objective procedure the multitude of behaviors involved in the testing and adjustment activities for the five missiles were classified into 23 major categories and 32 subcategories. This comprises a feasible number of representative categories by which testing and adjustment activities could be described and compared. They form, with respect to testing and adjustment activities, a set of basic categories which establish a framework for (a) the development of a guided missile rating structure and qualifications, and for (b) an integrated guided missile training and proficiency measurement program

Trouble Shooting

Considerations

Trouble shooting, as previously described, refers to the performance of procedures for the interpretation of trouble symptoms and for the isolation of a defective component or unit. The considerations involved in analyzing and describing the behavior involved in trouble-shooting activities are as follows:

1. The nature of the trouble-shooting behavior required for a particular equipment is highly dependent upon the construction of the equipment, e.g., the development of associated go-no-go test equipment and throw-away packages simplifies the job. However, for much of the test equipment used with the missiles being studied here, standard trouble-shooting procedures may still be required.

2. The behavior comprising trouble-shooting performance varies from behaviors that are comparable to the simplest testing and adjustment procedures to behavior that requires proficiency in the performance of testing and adjustment procedures plus skill in trouble-shooting practices and detailed knowledge of equipment circuitry and operation. In large part, an outstanding characteristic of trouble-shooting behavior is its non-routine nature in contrast to the relatively routine nature of the straight testing and adjustment activities previously discussed. This non-routine aspect is introduced because a man must decide when and where to make a particular test and adjustment as he trouble shoots and may not perform them as routine (checklist) check-out procedures.

3. If trouble-shooting behavior is thought of in terms of a continuum of behaviors (previously described in discussing testing and adjustment) which range from simple manipulation through precautionary behavior to decision-making (interpretation), then much of the behavior involved falls toward the precautionary and interpretation end of the continuum. It has been pointed out previously that the most concise way, for present purposes, to indicate precautions and interpretations is to state the equipment being used or worked with and, where necessary, to state what is being accomplished with this equipment.

4. As was stated for testing and adjustment activities, adequate and useful descriptions of behavior (for training and proficiency measurement purposes) should indicate the manipulative behavior involved and imply the precautions and interpretations involved. For trouble-shooting activities, interpretation and decision-making based on a knowledge of equipment operation becomes increasingly important.

Procedure

With the above considerations in mind, the following procedure was adopted for the description and categorization of the behaviors involved in trouble shooting:

STEP A. For each missile, engineering personnel analyzed the missile and its associated test and servicing equipment into chassis and sub-chassis units; for completeness of description the components within each chassis were listed in detail. This analysis is presented in Appendix F.

STEP B. The trouble-shooting procedures required for all missiles and their associated equipment were reviewed and the following descriptive categories were developed:

1. Using Go-No-Go Test Equipment. This kind of trouble shooting usually involves the use of complex equipment which required simple manipulations to operate and simple observation of results. The operator makes the necessary connections between the equipment being tested and the test equipment; presses a button or switch (or a series of buttons in a prescribed, perhaps timed, sequence); and notes or records lamps or go-no-go meters which indicate a defective or inoperative component.

2. Using an Unprogrammed Test Console. An unprogrammed test console, in the present context, is usually an elaborate arrangement of standard and specialized test equipment which can be operated by a detailed sequence of manipulations. The operator makes the necessary connections; sets up (adjusts and/or aligns or zeros) console components before and during testing; sets up recording instruments; and operates switches and control knobs according to a tabulated procedure. Indications of circuit and system performance are obtained by the interpretation of meter readings, timer readings, oscilloscope patterns, pen recordings, and indicator lamps. The determination of intolerance or out-of-tolerance functioning on the basis of these indications and the appropriate adjustment, replacement or repair involved can be performed with the aid of prepared trouble-shooting charts. This kind of job performance does not usually require the tracing of electronic circuits and performing

diagnostic trouble shooting as defined in Category 3 below. (In many job instances the indications obtained from an unprogrammed test console may be used to obtain information prior to the performance of diagnostic trouble shooting as described in Category 3; an experienced trouble shooter may also utilize the indications obtained from an unprogrammed test console without the aid of a standard chart for Category 3 diagnostic trouble shooting.)

3. Using Standard Equipment for Diagnostic Trouble Shooting. This kind of trouble shooting consists of the interpretation of symptoms of malfunctioning of the system in order to isolate a defective component or unit; this is accomplished by the trouble shooter on the basis of his past experience and by his examination of system functioning. The trouble shooter reads and uses block and schematic diagrams; he performs check procedures and interprets the results on the basis of his knowledge of the system; and he makes adjustments and alignments. This kind of trouble shooting can be divided into two categories based upon the complexity of the checks that are performed and the test equipment that is used:

   3a. Using less complex standard test equipment and making simple visual inspections. This kind of trouble shooting involves the use of such equipment as voltmeters, ohmmeters, etc., and the performance of visual inspections such as looking for bad relays, burned-out resistors, the presence of filament glow, etc. These indications are compared with normal or in-tolerance conditions and defective units are isolated on this basis.

3b. Using complex standard test equipment. This kind of trouble shooting includes the behaviors in 3a above and in addition involves the setting up and use of such equipment as oscilloscopes, synchroscopes, signal generators, etc. Skillful interpretation of the indications obtained from these equipments is required in order to diagnose and isolate the defect or defects causing a trouble symptom.

A further distinction is important in describing trouble-shooting behavior; this concerns the level of trouble shooting involved. This distinction is as follows:

To a component: Trouble shooting to a component involves localizing the source of trouble so that it is isolated to a defective "black box", chassis, or sub-chassis.

Within a component: Trouble shooting within a component involves localizing the source of trouble so that it is isolated to a defective part such as a resistor, relay, tube, etc.

STEP C. After (A) and (B) above were accomplished, project engineering personnel described each of the units derived in (A) in terms of categories 1, 2, 3a, or 3b listed above. Each unit was described in terms of these categories twice in order to describe both trouble shooting to a component and within a component. The results of this classification are presented in Chapter 2.

STEP D. The knowledge (theory) of missile operation that is associated with proficiency in performing complex trouble shooting was analyzed, described and compared for all missiles in terms of "Functional elements" or "system functions". The establishment of a unit for the description and comparison of knowledges presented a problem. Description and comparison could be made on various levels. For example, on a gross level, descriptive units such as "receiver", "servo system", and "hydraulic system" could be used. Description

in such terms suffers because of its generality. Receivers, servo systems, and hydraulic systems vary considerably and specification in these terms would not provide a definitive base for the establishment of training requirements and training curricula. On the other hand description on a minute level in terms of resistors, pentode and triode tubes, etc., would be inadequate. Major aspects of similarity and dissimilarity between missiles would be obscured; at this minute level all electronic equipments became quite similar. After some consideration, an intermediate descriptive level was established based upon "functional elements". A functional element can be defined, in this context, as a unit of a guided missile system that accomplishes a specific major function essential to the operation of the system. At this level a gross unit such as a receiver was analyzed into such elements as "preselector", "mixer", "if amplifier", "detector", "video amplifier", etc. A particular receiver might have all or some of these elements within it. Elements of this kind were employed as the basic units for the description and comparison of the knowledge or theory of missile operation. These elements were carefully named to facilitate the comparison between missiles and to reduce ambiguity. (In most instances element names do not correspond to the specific names used by missile manufacturers; this is so because identical circuits may be given different names by different manufacturers.)

To permit the comparison of the essential similarities and dissimilarities of missile functions and at the same time to keep sight of specific missile circuitry, missile operation is described in terms of the functional elements present in a particular missile and the circuits by which that particular function is performed in the missile. The results of this analysis are presented in tabular form with columns for each missile on one axis of the table and with rows for each functional element on the other axis; in the cells of the table the specific circuitry is given. This table and the

specific procedures followed in developing it are presented in Chapter 2.

Handling, Assembly and Servicing

The considerations involved in analyzing and describing the tasks and behaviors involved in handling, assembly and servicing activities are similar to those for testing and adjustment procedures. Behavior statements were written for handling, assembly and servicing activities to describe the observable behaviors involved in performing the procedures and in using the tools and equipment required for (1) the transfer and mating of missiles, missile containers, missile sections, and missile parts, and (2) the charging and bleeding of missile hydraulic and pneumatic systems. The behavior statements are also intended to infer the underlying knowledges involved, i.e., the precautions that must be followed and knowledge of when and where the behavior is to be performed. Knowledge of "when" is the ability to perform the behaviors at the proper time and in the prescribed sequences; knowledge of "where" refers to locations and routes covered in performing a behavior. "Where" and "when" knowledge is not specified in the behavior statements for the reason that they vary greatly from installation to installation and from time to time within a single installation depending upon changes in physical layout.

The behaviors required for handling, assembly, and servicing activities are, in contrast to testing and adjustment and trouble-shooting procedures, less technical especially with respect to electronics. Tasks center around the use of mechanical, hydraulic and pneumatic equipment. With respect to the manipulation-precautionary behavior-interpretation continuum described previously, handling, assembly and servicing activities involve less emphasis on interpretive behavior and require, primarily, manual, manipulative and precautionary behavior.

Handling and Assembly

In contrast to the analysis of testing and adjustment procedures, handling and assembly activities are not analyzed into many different specific tasks. The various handling and assembly tasks are less unique and less dependent on particular differences in equipment than are testing and adjustment procedures. In addition, the very specific details of handling and assembly activities, as indicated above, differ in different installations. For these reasons handling and assembly activities are analyzed generally under two main task titles, (1) Handling and Transfer, and (2) Assembly. As an example of the kinds of behavior statements written for this analysis, some of the statements written for Terrier handling and transfer activities are given below.

Handling and Transfer (Terrier)

Attaching slings and sling lifting attachments to a missile, missile sections or missile containers by hand and with hand tools.

Inspecting the external surfaces of a missile and missile parts for indications of damage or flaws.

Lifting and transporting a missile or missile sections with an electrically powered hoist.

Removing a missile or a missile section from a container or inserting a missile section into a container by manipulating canning stand levers, rams, etc.

Transporting a missile or missile section by hand on a stand, dolly or hydraulic-lift hand truck.

Inspecting propulsive grain for cracks.

Servicing

Servicing tasks, on the other hand, are defined and analyzed in much the same way as are testing and adjustment tasks. A servicing task is a particular work mission specified by established operating procedures and maintenance manuals; the name of a servicing task consists of the type of servicing operation being performed and the type of equipment being serviced. A portion of the behavior statements written to describe a particular servicing task is given below:

Charging a Nose Pneumatic System with Nitrogen (Dove)

Removing and replacing a missile cover plug by hand and with a screwdriver in preparation for missile servicing.

Opening a nitrogen charging valve with a special bleeding tool to bleed a missile pneumatic system.

Cocking an arming mechanism with a screwdriver; locking an arming mechanism with a safety pin after charging a missile pneumatic system.

Connecting and disconnecting a high pressure nitrogen line and a charging gage between a nitrogen storage bottle and a missile with a special wrench.

Opening and closing valves on a nitrogen line with reference to charging gage to charge a missile pneumatic system.

In a manner similar to the analysis of testing and adjustment procedures, handling, assembly, and servicing behavior statements were classified into categories of similar behaviors. Similarity was defined in terms of the criterion question, "In the performance of the behavior do men use the same kind of tools and procedures while working on similar kinds of equipment"? Classification of 200 behavior statements resulted in 12 behavioral categories. These categories were used as the basis for describing and comparing

handling, assembly and servicing procedures for the five missiles under consideration.

Summary

Thus far, this chapter has presented the problem undertaken by this investigation, namely: to establish descriptive units for missile tasks so that the skills and knowledges involved in the duties of a guided missileman could be analyzed, described and compared for a number of guided missiles. This over-all comparison and integration should provide an objective structure and specific information for the requirements of missileman ratings and for the development of training programs and curricula. This chapter has presented procedures and methodology by which the behaviors involved in guided missile tasks can be described and integrated for a number of different guided missile systems. The final pages of the chapter discuss the extent of the coverage and the limitation of the present analyses.

Coverage and Limitations

As pointed out, this study is restricted to those tasks which comprise the duties of a guided missileman; guided missile tasks performed by other Navy ratings are listed but not studied in this report. The determination of just what aspects of guided missiles and just what tasks should comprise a guided missile rating must be decided on the basis of careful job analysis. Previous work[1] has

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[1] Glaser, R.; Hahn, J.; and Phillips, J.C. "Collecting and Compiling Task Information for Newly Developed Guided Missiles." Bureau of Naval Personnel Technical Bulletin 53-2, American Institute for Research, August 1953.

and:

Glaser, R.; Talbert, G.E.; and Carlucci, C.A. Guided Missile Personnel Research: Report No. 1, American Institute for Research, June 1952.

considered it most effective to treat this problem in terms of job overlap, i.e., the identification of those skills and knowledges required by the new missile that overlap with the skills and knowledges possessed by existing manpower. Personnel with certain kinds of training may be capable of performing guided missile duties without additional training; others may recuire brief on-the-job training or some brief additional formal training, e.g., transition training from equipment they already know to similar, new or modified equipment. The consideration of overlap yields significant information for the determination of (a) sources of manpower which are available for the operation and maintenance of the new weapon, (b) the degree to which training is necessary for this available manpower to perform guided missile duties, (c) the possible necessity for the establishment of job codes and (d) the extent and structure of the duties in a guided missile rating. It has been found most feasible to identify overlapping activities in terms of the duties required for the operation and maintenance of major pieces of equipment that are used with a particular missile that are similar to equipment operated and maintained by existing Navy ratings. For example, in Terrier, external guidance and control employs the Mark 25 Mod 6 radar which is a modification of the widely used Mark 25 Mod 2. Terrier launchers are similar in many respects to existing types of gun mounts.

As a very general rule, job analysis has indicated that external guidance and control duties can be assigned to existing ratings, whereas tasks concerned with internal guidance, i.e., the actual missile or "bird" and its associated test and servicing equipment, comprise the duties of missileman ratings. There are necessary exceptions to the general rule: for example, the Petrel missile consists in part of a Mark 13 or Mark 21 torpedo which can be serviced by a torpedoman; Petrel and Regulus contain standard autopilots which can be repaired by an aviation electrician; and especially

notable exception may occur for Regulus when it is submarine launched, here it may be necessary for a submariner missileman to perform duties concerned with both the bird and the external guidance and control equipment.

In this report technical manuals, job analysis data and field interview information were intensively reviewed and carefully weighed decisions were made concerning the equipments to be assigned to missileman ratings and the equipment to be considered overlap and assigned to existing Navy ratings. The major equipments assigned to the missileman and the major equipment assigned to overlapping ratings are described in Appendix A. If the information on any equipment with which the missileman may be concerned has not been available or has been too preliminary for the purposes of this report, it is so indicated in this Appendix.

Finally, two limitations of the data on which this report is based should be kept in mind. One, the extent of the analysis and description possible for the tasks involved for the equipment with which a missileman is concerned and the stability of this description, is dependent upon the adequacy and completeness of the information available for each equipment. This in turn is dependent upon the developmental status of the missile. Missiles and equipment within particular missiles differ in this respect. The analysis in this report is based upon information which was judged to be relatively "firm" and predictive, in the main, of the anticipated actual operational situation. Tasks concerned with temporary equipment or equipment used only for missile test and evaluation, e.g., extensive telemetering equipment, were not included in this report. Secondly, tasks which were specific to particular operational installations and which do not appear to be generalizable to future operations are not described in this report.

CHAPTER 2

RESULTS

This chapter presents the results obtained from the application of the procedures described in Chapter 1. The essential purpose of this chapter is to present in as concise and comprehensive a manner as possible a comparative analysis of the skills and knowledges required for the operation and maintenance of five guided missiles with respect to the duties of the guided missileman ratings. The major findings of the analysis are presented in descriptive and tabular form in this chapter. Other detailed results are presented in appendices which accompany this report. Three sections comprise this chapter, namely, testing and adjustment procedures; trouble shooting; and handling, assembly and servicing. For each of these sections an analysis of the task behaviors most likely to be performed by the guided missileman is presented for two surface-launched missiles, Terrier and Regulus, and three air-launched missiles, Sparrow, Petrel and Dove.

Testing and Adjustment Procedures

The results of the analysis of testing and adjustment procedures are presented in tabular fashion in Table 1; the 23 major behavioral categories and 32 sub-categories which were developed on the basis of the procedure described in Chapter 1 are listed along the vertical axis or rows of the table and each missile is listed along the horizontal axis or columns of the table. Each entry in the table contains the percentage of all the behavior statements for a particular missile that constitute a particular category or sub-category. It should be remembered that three kinds of behavior statements are incorporated into this table: behavior statements describing testing and adjustment

procedures for missile components, behavior statements describing testing and adjustment procedures for missile test equipment, and behavior statements describing the testing and adjustment procedures for external guidance equipment; the latter occurs only for Regulus. Detailed lists of the tasks and associated behavior statements for each missile are presented in Appendix B accompanying this report. The behavior statements for all missiles included in each of the behavioral categories are presented in Appendix C.

Occasionally in Table 1, and Figures 1 and 2 which will be described, it may appear that certain categories for a particular missile have been obviously omitted. This can be the result of the following factors: (a) the behaviors involved in the category are performed in the course of automatic or semi-automatic testing procedures and are not performed by specific effort on the part of the guided missileman; (b) the behaviors involved have not been included or reported in on-the-job checklists or maintenance manuals, probably because of uncertain engineering development; (c) the behaviors involved are concerned with equipment which is more highly classified than this report.

These above limitations, however, are counterbalanced by the fact that the data collected for each missile have been as detailed and exhaustive as available information for the present developmental stage of the missile would permit. It is believed that adequate information has been obtained in order to (a) specify the primary skills and knowledges required by a missileman working with a particular missile, and (b) to compare these skills and knowledges for different missiles. Specifically, the information available for Terrier and Sparrow has been detailed, organized and complete; for Petrel and Dove the available information has been less detailed but a relatively complete task picture was apparent; for Regulus with its three types of guidance systems, the available information has been less well organized and has contained certain gaps in completeness.

The last line in Table 1 shows the number of behavior statements involved for each missile; 115 for Terrier, 270 for Regulus, 330 for Sparrow, 54 for Petrel, and 23 for Dove.[1] The large number for Sparrow reflects, to a large extent, the fact that Sparrow has many kinds of special test consoles which require testing and adjustment procedures. The behavior statements for Regulus, unlike the other missiles, are inflated to some extent as they describe tasks required for the testing and adjustment of complex external guidance equipments which may be required for the submariner. Petrel and Dove require relatively few testing and adjustment tasks and consequently they have the smallest number of behavior statements.

Inspecting the results shown in Table 1 for each missile separately, the categories that include the largest percentages of behavior statements for each missile give an indication of the most frequently required testing and adjustment behaviors that must be performed by a missileman concerned with that particular missile. The major categories listed in order of the percentage of behavior statements classified into a category are given on the following pages for each missile.

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[1] Actually, 771 behavior statements were written; the totals for each missile reported here add to 792. This occurs because, for the most complete description of the behavior involved, it was decided to sort a small number of behavior statements into more than one category. The percentages in Table 1 are based on the 792 figure.

Terrier

Behavioral Categories	Percentage of Behavior Statements Constituting Each Category
Using synchroscopes and oscilloscopes	13.9
Adjusting controls, setting switches and reading quantitative indications on meters or gages	10.4
Adjusting circuit performance with potentiometers, coupling loops, tuning slugs and trimmer condensers	7.0
Connecting and disconnecting microwave fittings	7.0
Operating mechanical test equipment and using hand tools	7.0
Performing numerical operations and using tables and graphs	7.0
Setting up and using oscillographic recorders	7.0
Adjusting microwave oscillators, waveguides, and resonant cavities	6.1
Checking and adjusting power supplies	6.1
Connecting and disconnecting electrical, pneumatic and hydraulic fittings	5.2
Manipulating test console front panel switches and controls and observing go-no-go indications	5.2
Using and calibrating simple meters to measure voltage, current, and resistance	5.2
Setting up, using and calibrating frequency meters	3.5
Setting up and using standard and special signal generators (align and adjust)	3.5
Balancing electronic circuits by component adjustment, or replacement	2.6
Servicing and adjusting relays	1.7
Timing with stop watches	1.7
	100.1

Regulus

Behavioral Categories	Percentage of Behavior Statements Constituting Each Category
Setting up and using standard and special signal generators (align and adjust)	20.0
*Using synchroscopes and oscilloscopes	12.6
Using and calibrating simple meters to measure voltage, current, and resistance	12.2
Adjusting microwave oscillators, waveguides, and resonant cavities	7.4
Performing numerical operations and using tables and graphs	6.7
Manipulating test console front panel switches and controls and observing go-no-go indications	5.9
Adjusting circuit performance with potentiometers, coupling loops, tuning slugs and trimmer condensers	4.4
Connecting and disconnecting electrical, pneumatic and hydraulic fittings	4.4
*Making mechanical and electrical adjustments of synchros, counters and gear training (in Shoran-type range systems)	4.4
Adjusting controls, setting switches and reading quantitative indications on meters or gages	4.1
Operating mechanical test equipment and using hand tools	4.1
Setting up, using and calibrating frequency meters	3.7
*Checking and adjusting power supplies	3.0
*Servicing and adjusting relays	2.2
Timing with stop watches	1.5
Connecting and disconnecting microwave fittings	1.1
*Balancing electronic circuits by component adjustment, or replacement	.7

*The asterisk indicates that the majority of the behavior statements comprising the category involved are concerned with external guidance equipment.

REGULUS (Cont'd)

Behavioral Categories	Percentage of Behavior Statements Constituting Each Category
Setting up and using a special servo analyzer	.7
Reading schematic and wiring diagrams to locate test points	.4
Setting up and using oscillographic recorders	.4
	99.9

Sparrow

Using and calibrating simple meters to measure voltage, current, and resistance	13.0
Checking and adjusting power supplies	12.4
Using synchroscopes and oscilloscopes	11.8
Adjusting controls, setting switches and reading quantitative indications on meters or gages	7.9
Adjusting circuit performance with potentiometers, coupling loops, tuning slugs and trimmer condensers	7.6
Operating mechanical test equipment and using hand tools	7.0
Adjusting microwave oscillators, waveguides, and resonant cavities	5.2
Setting up and using standard and special signal generators (align and adjust)	4.5
Connecting and disconnecting electrical, pneumatic and hydraulic fittings	4.2
Balancing electronic circuits by component adjustment, or replacement	3.9
Performing numerical operations and using tables and graphs	3.3
Setting up, using and calibrating frequency meters	3.0
Setting up and using oscillographic recorders	2.7
Using capacitor and resistor decade boxes for tuning and aligning electronic circuits by component substitution	2.7

Sparrow (Cont'd)

Behavioral Categories	Percentage of Behavior Statements Constituting Each Category
Reading schematic and wiring diagrams to locate test points	2.4
Timing with stop watches	2.4
Manipulating test console front panel switches and controls and observing go-no-go indications	2.1
Connecting and disconnecting microwave fittings	.9
Making hi-pot. voltage checks or insulation breakdown checks	.9
Servicing and adjusting relays	.9
Testing and adjusting free and rate gyros	.9
	99.7

Petrel

Adjusting circuit performance with potentiometers, coupling loops, tuning slugs and trimmer condensers	20.3
Using synchroscopes and oscilloscopes	14.8
Using and calibrating simple meters to measure voltage, current, and resistance	11.1
Adjusting microwave oscillators, waveguides, and resonant cavities	9.3
Setting up and using standard and special signal generators (align and adjust)	9.3
Operating mechanical test equipment and using hand tools	7.4
Performing numerical operations and using tables and graphs	7.4
Adjusting controls, setting switches and reading quantitative indications on meters or gages	5.6
Connecting and disconnecting microwave fittings	5.6
Servicing and adjusting relays	3.7

Petrel (Cont'd)

Behavioral Categories	Percentage of Behavior Statements Constituting Each Category
Checking and adjusting power supplies	1.9
Making hi-pot. voltage checks or insulation breakdown checks	1.9
Timing with stop watches	1.9
	100.2

Dove

Using and calibrating simple meters to measure voltage, current, and resistance	26.1
Checking and adjusting power supplies	21.7
Manipulating test console front panel switches and controls and observing go-no-go indications	17.4
Operating mechanical test equipment and using hand tools	17.4
Using synchroscopes and oscilloscopes	8.7
Adjusting circuit performance with potentiometers, coupling loops, tuning slugs and trimmer condensers	4.3
Connecting and disconnecting electrical, pneumatic and hydraulic fittings	4.3
	99.9

Considering all missiles together, Figure 1 lists the behavioral categories in order of their average rank order of frequency of occurrence. In the table the first category "Using synchroscopes and oscilloscopes" is, on the average for the five missiles, the most frequently used behavior category, i.e., on the average the highest percentage of behavior statements for each missile has been classified into that category. Generally then, for all missiles considered together Figure 1 shows the most frequently and the least frequently occurring behavioral categories of testing and adjustment procedures.

The bar charts in Figure 1 present the percentages given in Table 1 in a more graphic manner; these percentage bars show for each missile the percentage of all behavior statements descriptive of testing and adjustment procedures which fall into each behavioral category. Figure 1 shows the generality and uniqueness of each of the behavioral categories, i.e., some categories of behavior are present in all or some missiles whereas some categories are unique to one missile. The behavioral categories listed in order of their generality and uniqueness are given below.

In the performance of testing and adjustment procedures, the following behavioral categories are common to all five missiles:

Using synchroscopes and oscilloscopes

Using and calibrating simple meters to measure voltage, current, and resistance

Adjusting circuit performance with potentiometers, coupling loops, tuning slugs and trimmer condensers

Operating mechanical test equipment and using hand tools

Checking and adjusting power supplies

In the performance of testing and adjustment procedures, the following behavioral categories are common to four missiles; Terrier, Regulus, Sparrow, and either Petrel or Dove:

Adjusting microwave oscillators, waveguides and resonant cavities

Adjusting controls, setting switches, and reading quantitative indications on meters and gages

Setting up and using standard and special signal generators (align and adjust)

Performing numerical operations and using tables and graphs

Connecting and disconnecting electrical, pneumatic and hydraulic fittings

Manipulating test console front panel switches and controls and observing go-no-go indications

Connecting and disconnecting microwave fittings

Timing with stop watches

Servicing and adjusting relays

In the performance of testing and adjustment procedures, the following behavioral categories are common to two or three missiles:

Setting up, using and calibrating frequency meters

Setting up and using oscillographic recorders

Balancing electronic circuits by component adjustment or replacement

Reading schematic and wiring diagrams to locate test points

Making hi-pot. voltage checks or insulation breakdown checks

In the performance of testing and adjustment procedures, the following behavioral categories are unique to one particular missile:

Making mechanical and electrical adjustments of synchros, counters and gear trains (in Shoran-type range systems)

Using capacitor and resistor decade boxes for tuning and aligning electronic circuits by component substitution

Setting up and using a special servo analyzer

Testing and adjusting free and rate gyros

In Figure 2 the percentages given in Table 1 are presented in an over-all series of bar charts. The numbers on the horizontal axes of these charts refer to the behavioral category numbers employed in Figure 1. The series of charts in Figure 2 show clearly the spread of variety of behavioral categories involved in the testing and adjustment procedures for each of the missiles under consideration. Sparrow and Regulus testing and adjustment procedures fall into the largest number of different categories, Sparrow covering 21 categories and Regulus covering 20 categories. Terrier testing and adjustment procedures cover 17 categories. Petrel and Dove testing and adjustment procedures involve the fewest number of different categories, Petrel covers 13 categories and Dove covers seven categories. The extent of the subject matter coverage of training curricula in testing and adjustment procedures for each missile should be related to the number of behavioral categories involved.

Surface-launched and Air-launched Missiles - With respect to the differences between the surface-launched missiles, Terrier and Regulus, and the air-launched missiles, Sparrow, Petrel and Dove, Figure 2 indicates a difference in the homogeneity of categories within these two groupings. The two surface-launched missiles are quite homogenous in the sense that they have a large number of behavioral categories in common with respect to testing and adjustment procedures. The three air-launched missiles are more diverse, ranging from Dove in which testing and adjustment procedures are classified into seven categories to Sparrow where testing and adjustment procedures cover 21 different categories.

Table 1

The Percentage of Behavior Statements in Each Testing and Adjustment Behavioral Category and Sub-Category for Each Missile

Behavioral Categories	Terrier	Regulus	Sparrow	Petrel	Dove
Adjusting circuit performance with potentiometers, coupling loops, tuning slugs and trimmer condensers	7.0	4.4	7.6	20.3	4.3
a. AFC, AGC and control bias voltages of rf and if amplifiers	2.6	1.9	.3	9.3	4.3
b. Gain of dc and af amplifiers	—	.4	3.3	1.9	—
c. Frequency of af oscillators	—	—	1.8	1.9	—
d. Resonant frequency and coupling of rf or if circuits	1.7	1.5	.3	—	—
e. Voltage output of resistive voltage dividers	1.7	.7	.9	3.7	—
f. Electrical and mechanical zero of control surfaces and gyro mounts	.9	—	.3	3.7	—
g. Tune resolvers	—	—	.6		—
Adjusting controls, setting switches and reading quantitative indications on meters or gages	10.4	4.1	7.9	5.6	—
Adjusting microwave oscillators, waveguides, and resonant cavities	6.1	7.4	5.2	9.3	—
a. Tune klystrons and lighthouse tubes	4.3	1.9	2.7	1.9	—
b. Tune magnetrone	—	2.6	—	—	—
c. Measure and adjust klystron frequency pulling	1.7	—	.9	—	—

Table 1 (Cont'd)

Behavioral Categories	Terrier	Regulus	Sparrow	Petrel	Dove
d. Adjust wave guides and resonant cavities	--	.4	.9	1.9	--
e. Measure power output	--	2.6	--	--	--
f. Construct and adjust delay lines	--	--	.6	1.9	--
g. Measure antenna pattern	--	--	--	5.6	--
Balancing electronic circuits by component adjustment or replacement	2.6	.7	3.9	--	--
Checking and adjusting power supplies	6.1	3.0	12.4	1.9	21.7
a. Measurement of ripple voltage	.9	--	3.3	--	--
b. Determination of regulation with variable input and/or variable loads	1.7	1.1	3.9	--	--
c. Measurement of operation at specified input and load	3.5	1.5	5.2	1.9	4.3
d. Carbon pile regulator adjustments	--	--	--	--	17.4
Connecting and disconnecting electrical, pneumatic and hydraulic fittings	5.2	4.4	4.2	--	4.3
Connecting and disconnecting microwave fittings	7.0	1.1	.9	5.6	--
Making hi-pot. voltage checks or insulation breakdown checks	--	--	.9	1.9	--
Making mechanical and electrical adjustments of synchros, counters and gear trains (in Shoran-type range systems)	--	4.4	--	--	--

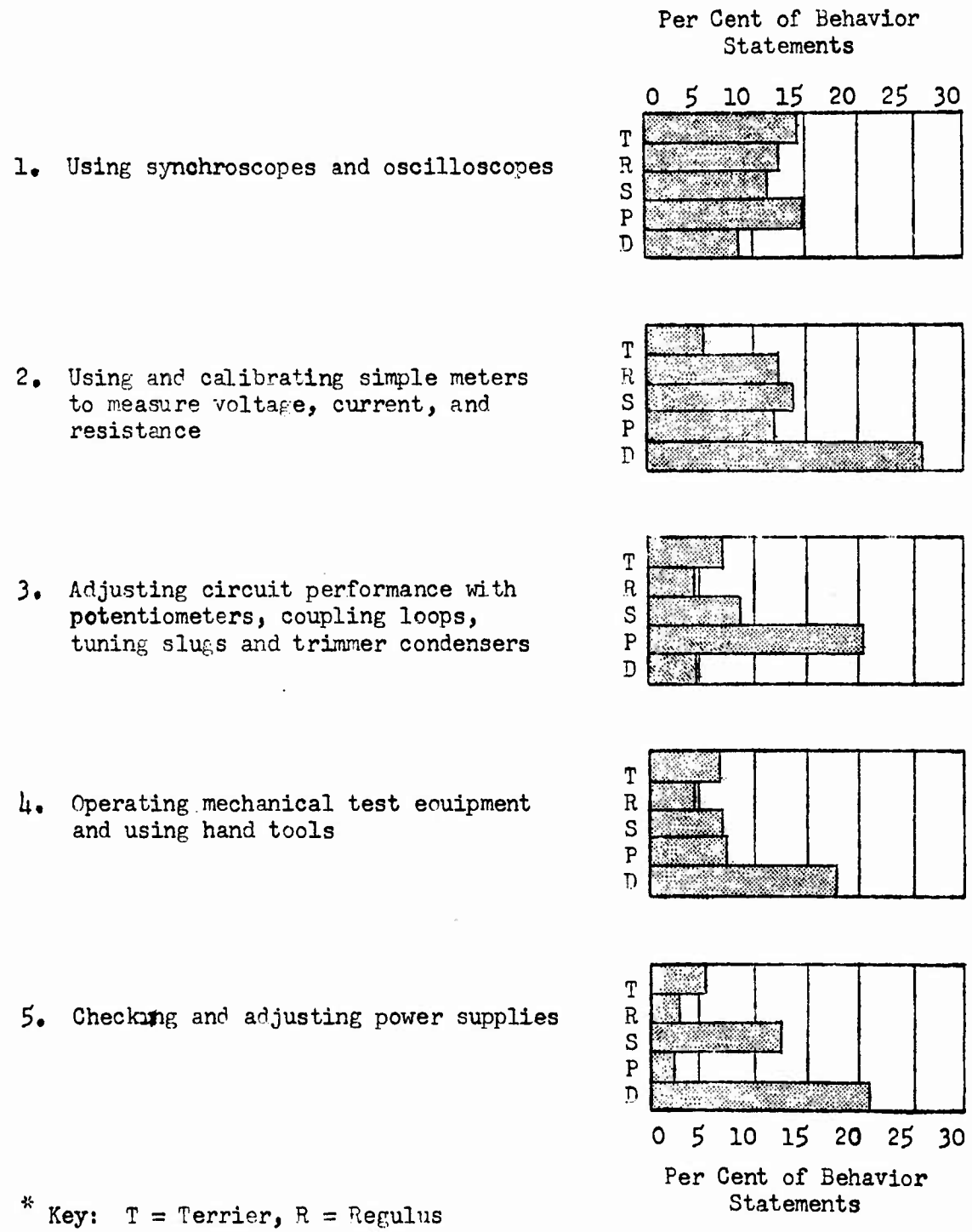
Table 1 (Cont'd)

Behavioral Categories	Terrier	Regulus	Sparrow	Petrel	Dove
Manipulating test console front-panel switches and controls and observing go-no-go indications	5.2	5.9	2.1	--	17.4
Operating mechanical test equipment and using hand tools	7.0	4.1	7.9	7.4	17.4
a. Pressurize component housings	--	.7	--	--	--
b. Wiring, using soldering iron and pliers	--	--	1.8	--	--
c. Mechanical adjustments	.9	1.1	3.3	5.6	13.0
d. Mounting missile and missile components in stands and installing mechanical transducers	5.2	1.5	1.2	1.9	4.3
e. Calibrating and adjusting altitude sensing devices and pressure gages	.9	.7	.6	--	--
Performing numerical operations and using tables and graphs	7.0	6.7	3.3	7.4	--
a. Performing arithmetic and algebraic operations	7.0	3.7	2.1	5.6	--
b. Using and constructing tables and graphs	--	3.0	1.2	1.9	--
Reading schematic and wiring diagrams to locate test points	--	.4	2.4	--	--
Servicing and adjusting relays	1.7	2.2	.9	3.7	--
Setting up, using and calibrating frequency meters	3.5	3.7	3.0	--	--
a. Heterodyne frequency meters	1.7	2.6	--	--	--
b. Absorption type frequency meter	1.7	1.1	.9	--	--

Table 1 (Cont'd)

Behavioral Categories	Terrier	Regulus	Sparrow	Petrel	Dove
c. EPUT meter	---	---	2.1	---	---
Setting up and using a special servo analyzer	---	.7	---	---	---
Setting up and using oscillographic recorders	7.0	.4	2.7	---	---
Setting up and using standard and special signal generators (align and adjust)	3.5	20.0	4.5	9.3	---
a. Rf generators	.9	7.0	---	7.4	---
b. Audio frequency generators	.9	.4	1.8	1.9	---
c. Pulse generators	---	12.6	1.8	---	---
d. Rf attenuators	1.7	---	.9	---	---
Testing and adjusting free and rate gyros	---	---	.9	---	---
Timing with stopwatches	1.7	1.5	2.4	1.9	---
Using and calibrating simple meters to measure voltage, current, and resistance	5.2	12.2	13.0	11.1	26.1
Using capacitor and resistor decade boxes for tuning and aligning electronic circuits by component substitution	---	---	2.7	---	---
Using synchroscopes and oscilloscopes	13.9	12.6	11.8	14.8	8.7
Total Number of Behavioral Statements	115	270	330	54	23

Fig. 1. The Percentage of Behavior Statements in Each Major Testing and Adjustment Category for Each Missile.*



* Key: T = Terrier, R = Regulus
S = Sparrow, P = Petrel, D = Dove

Fig. 1 (Cont')

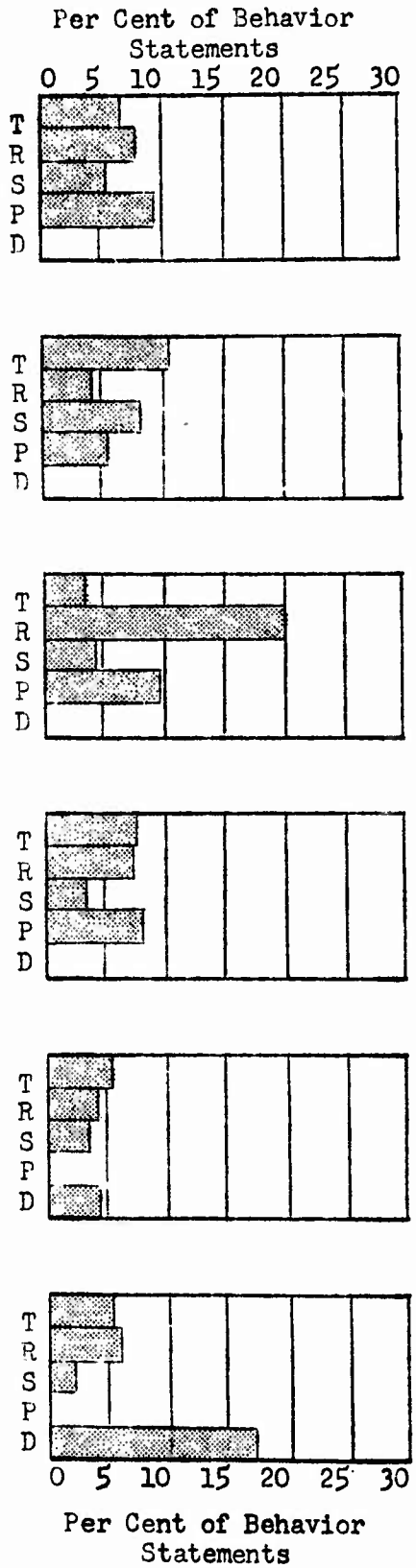
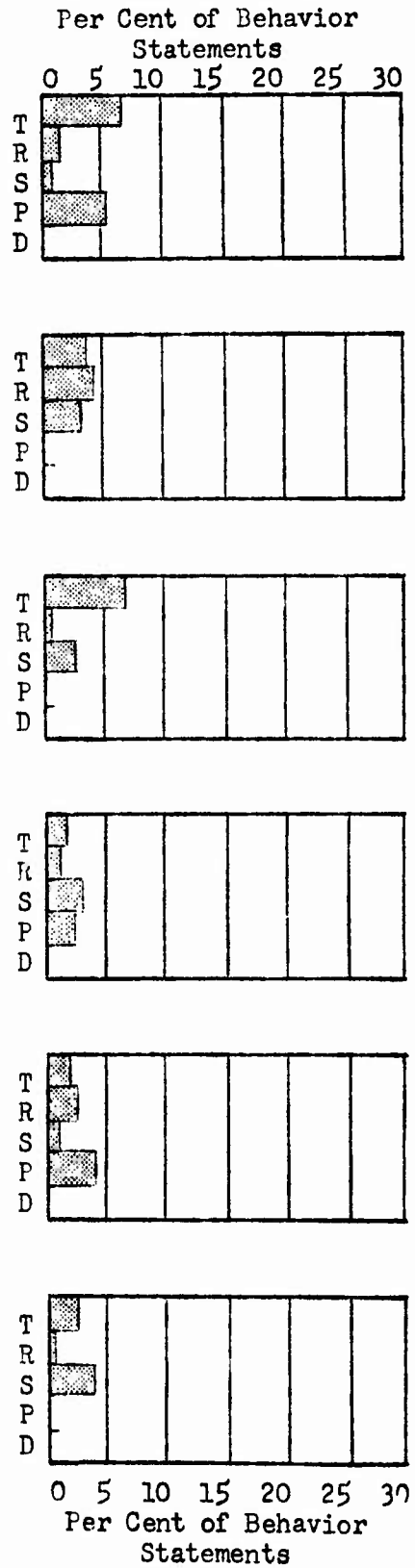

Per Cent of Behavior Statements
0 5 10 15 20 25 30
T
R
S
P
D
6. Adjusting microwave oscillators, waveguides, and resonant cavities
7. Adjusting controls, setting switches and reading quantitative indications on meters or gages
8. Setting up and using standard and special signal generators (align and adjust)
9. Performing numerical operations and using tables and graphs
10. Connecting and disconnecting electrical, pneumatic and hydraulic fittings
11. Manipulating test console front panel switches and controls and observing go-no-go indications
0 5 10 15 20 25 30
Per Cent of Behavior Statements

Fig. 1 (Cont'd)



12. Connecting and disconnecting microwave fittings

13. Setting up, using and calibrating frequency meters

14. Setting up and using oscillographic recorders

15. Timing with stop watches

16. Servicing and adjusting relays

17. Balancing electronic circuits by component adjustment, or replacement

Fig. 1 (Cont'd)

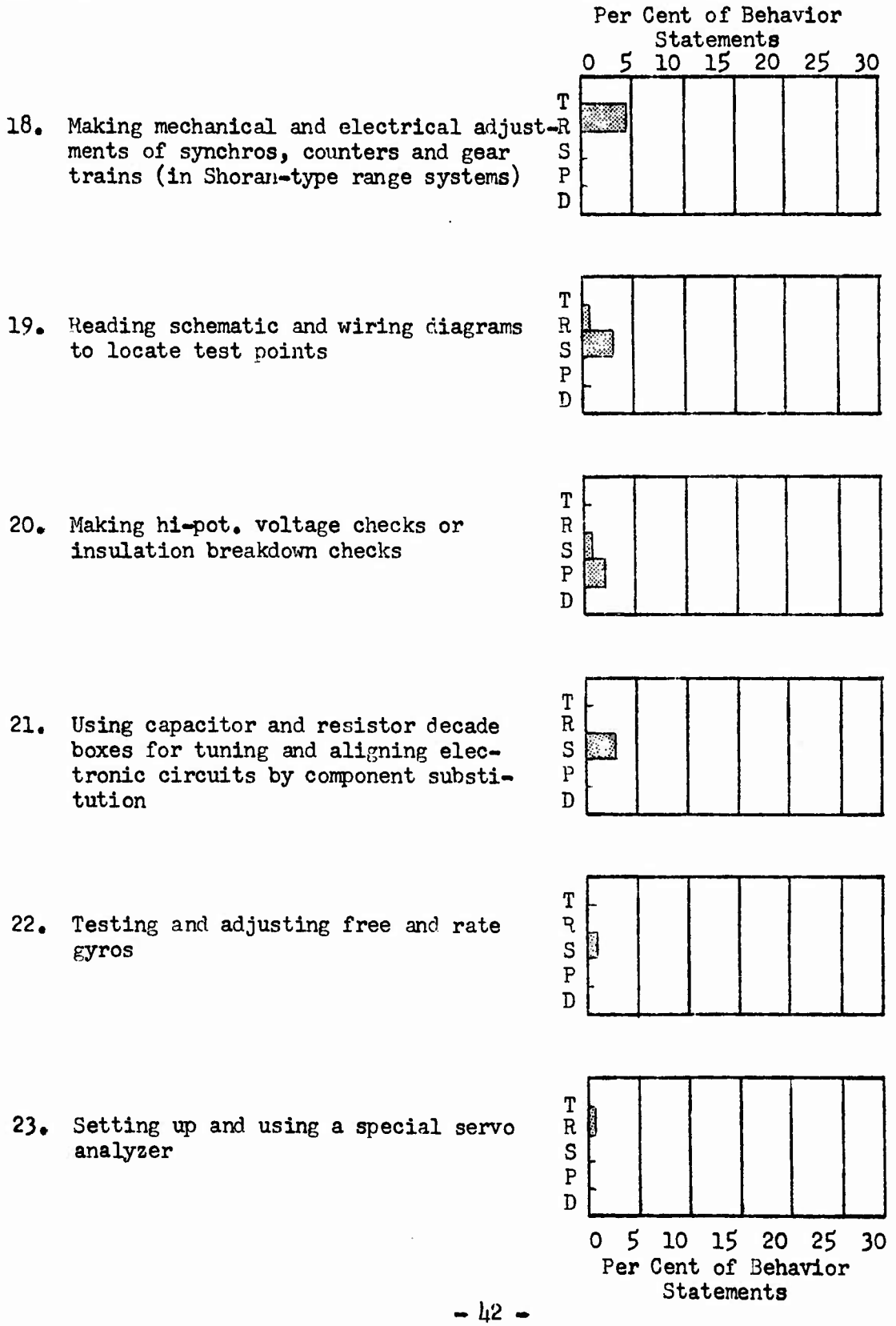
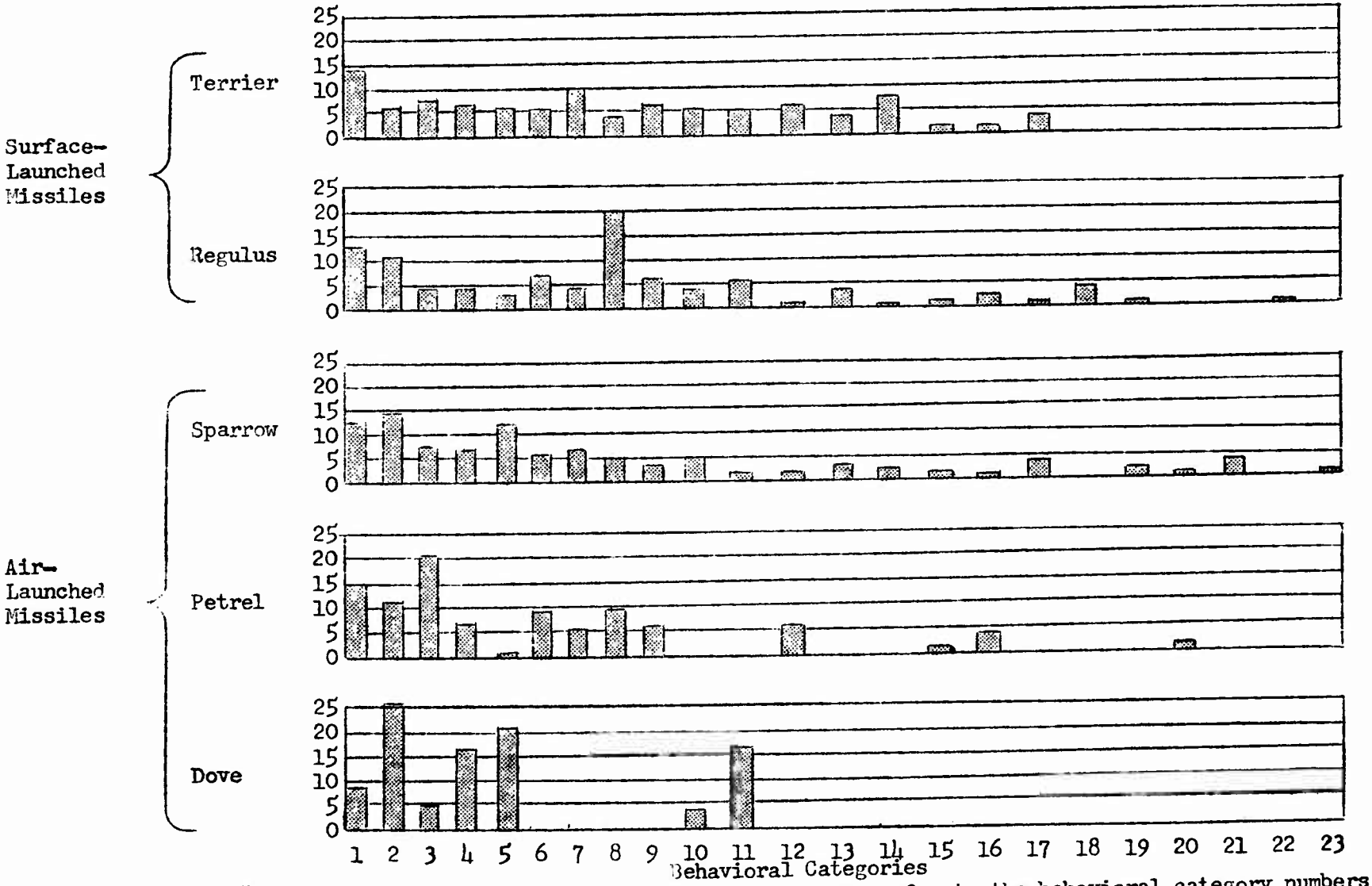

Per Cent of Behavior Statements
0 5 10 15 20 25 30
T
R
S
P
D
18. Making mechanical and electrical adjustments of synchros, counters and gear trains (in Shoran-type range systems)
19. Reading schematic and wiring diagrams to locate test points
20. Making hi-pot. voltage checks or insulation breakdown checks
21. Using capacitor and resistor decade boxes for tuning and aligning electronic circuits by component substitution
22. Testing and adjusting free and rate gyros
23. Setting up and using a special servo analyzer
0 5 10 15 20 25 30
Per Cent of Behavior Statements

Fig. 2. An Over-All Comparison of the Percentage of Behavior Statements in Each Major Testing and Adjustment Category.*



*The numbers on the horizontal axes of these charts refer to the behavioral category numbers employed in Figure 1.

Trouble Shooting

In accordance with the procedure described in Chapter 1, the results of the analysis of trouble-shooting behavior for the five missiles under consideration is presented in Table 2, Figures 2a and 2b, and Table 3. Table 2 lists the major chassis (and sub-chassis) of each missile and its associated test equipment; to the right of each chassis the numbers 1, 2, 3a, and 3b represent the trouble-shooting behavior category applicable to that chassis. The categories to which these numbers refer are the following:

1. Using Go-No-Go Test Equipment
2. Using an Unprogrammed Test Console
3a. Using Standard Equipment for Diagnostic Trouble Shooting: Using less complex standard test equipment and making simple visual inspections
3b. Using Standard Equipment for Diagnostic Trouble Shooting: Using complex standard test equipment

Explicit descriptions of these categories are given in Chapter 1 and are repeated here for easy reference:

1. Using Go-No-Go Test Equipment. This kind of trouble shooting usually involves the use of complex equipment which requires simple manipulations to operate and simple observation of results. The operator makes the necessary connections between the equipment being tested and the test equipment; presses a button or switch (or a series of buttons in a prescribed, perhaps timed sequence); and notes or records lamps or go-no-go meters which indicate a defective or inoperative component.

2. Using an Unprogrammed Test Console. An unprogrammed test console, in the present context, is usually an elaborate arrangement of standard and specialized test equipment which can be operated by a detailed sequence of manipulations. The operator makes the necessary connections between the equipment being tested and the test equipment; sets up (adjusts and/or aligns or zeros) console components before and during testing; sets

up recording instruments; and operates switches and control knobs according to a tabulated procedure. Indications of circuit and system performance are obtained by the interpretation of meter readings, timer readings, oscilloscope patterns, pen recordings, and indicator lamps. The determination on intolerance or out-of-tolerance functioning on the basis of these indications and the appropriate adjustment, replacement or repair involved can be performed with the aid of prepared trouble-shooting charts. This kind of job performance does not usually require the tracing of electronic circuits and performing diagnostic trouble shooting as defined in Category 3 below.

(In many job instances the indications obtained from an unprogrammed test console may be used to obtain information prior to the performance of diagnostic trouble shooting as described in Category 3; an experienced trouble shooter may also utilize the indications obtained from an unprogrammed test console without the aid of a standard chart for Category 3 diagnostic trouble shooting.)

3. Using Standard Equipment for Diagnostic Trouble Shooting. This kind of trouble shooting consists of the interpretation of symptoms of malfunctioning of the system in order to isolate a defective component or unit; this is accomplished by the trouble shooter on the basis of his past experience and by his examination of system functioning. The trouble shooter reads and uses block and schematic diagrams; he performs check procedures and interprets the results on the basis of his knowledge of the system; and he makes adjustments and alignments. This kind of trouble shooting can be divided into two categories based upon the complexity of the checks that are performed and the test equipment that is used:

3a. Using less complex standard test equipment and making simple visual inspections. This kind of trouble shooting involves the use of such equipment as voltmeters, ohmmeters, etc., and the performance of visual inspections such as looking for bad relays, burned-out resistors, the presence of filament glow, etc. These indications are compared with normal or in-tolerance conditions and defective units are isolated on this basis.

3b. Using complex standard test equipment. This kind of trouble shooting includes the behaviors in 3a above and in addition involves the setting up and use of such equipment as oscilloscopes, synchroscopes, signal generators, etc. Skillful interpretation of the indications obtained from these equipments is required in order to diagnose and isolate the defect or defects causing a trouble symptom.

In Table 2, the kind of trouble shooting required for each chassis is given separately for trouble-shooting "to a component" and "within a component". These two classifications are defined as follows:

To a component - Trouble shooting to a component involves localizing the source of trouble so that it is isolated to a defective "black box", chassis or sub-chassis.

Within a component - Trouble shooting within a component involves localizing the source of trouble so that it is isolated to a defective part such as a resistor, relay, tube, etc.

The word "none" is used in the table for the following reasons: (a) when trouble shooting "to" a chassis is sufficient to localize a defect and no "within" trouble shooting is necessary; (b) when, in order to localize a defect, trouble shooting is performed directly "within" a chassis and no "to" trouble shooting is performed; and (c) when a defect in a chassis is immediately obvious and no "to" or "within" trouble shooting is usually necessary for that chassis.

The analysis presented is concerned with the missile and its associated special equipment; the trouble shooting of standard test equipment such as voltmeters, tube testers, oscilloscopes, etc., is not considered here. (A listing of the standard test sets issued for use with each missile and its associated equipment is presented in Appendix G.) A detailed breakdown of the components of each of the chassis listed in Table 2 is given in Appendix F.

Figures 2a and 2b present the results given in Table 2 in more graphic fashion. Figure 2a is concerned with trouble shooting "to" a chassis and shows for each missile the percentage of all chassis, in a missile and its associated equipment, that require trouble-shooting behavior of the kind described in each of the four categories. Figure 2b shows the same information for trouble shooting "within" a chassis. The percentages for a missile may add to more than 100 per cent; this occurs when one chassis requires trouble-shooting behavior that falls in more than one category. For the five missiles being studied, the bar charts in Figures 2a and 2b offer a comparison of the kind of trouble-shooting behavior required as part of the duties of the guided missileman. Considering each missile separately, with respect to the kind of trouble-shooting behavior required for the component chassis of a missile and its associated special equipment, these data indicate the following:

Terrier

Trouble shooting to a component —

36.4% of the components require diagnostic trouble shooting employing less complex test equipment and simple visual inspections.

30.3% of the components employ the use of an unprogrammed test console.

18.2% of the components employ the use of go-no-go test equipment.

33.3% of the components do not require "to a component" trouble shooting.

Trouble shooting within a component —

69.7% of the components require diagnostic trouble shooting employing less complex test equipment and simple visual inspections.

30.3% of the components require diagnostic trouble shooting using complex test equipment.

Regulus

Trouble shooting to a component —

52.5% of the components require diagnostic trouble shooting using complex test equipment.

42.5% of the components require diagnostic trouble shooting employing less complex test equipment and making visual inspections.

(For 5% of the components adequate information was not available to infer the kind of trouble-shooting behavior required.)

Trouble shooting within a component —

75.0% of the components require diagnostic trouble shooting using complex test equipment.

20.0% of the components require diagnostic trouble shooting employing less complex test equipment and simple visual inspections.

5.0% of the components do not require "within a component" trouble shooting.

Sparrow

Trouble shooting to a component —

85.5% of the components require diagnostic trouble shooting employing less complex test equipment and simple visual inspections.

14.5% of the components employ the use of an unprogrammed test console.

Trouble shooting within a component —

72.4% of the components require diagnostic trouble shooting employing less complex test equipment and simple visual inspections.

27.6% of the components require diagnostic trouble shooting using complex test equipment.

13.2% of the components employ the use of an unprogrammed test console.

Petrel

Trouble shooting to a component —

64.5% of the components employ the use of an unprogrammed test console.

54.8% of the components require diagnostic trouble shooting employing less complex test equipment and simple visual inspections.

3.2% of the components require diagnostic trouble shooting using complex test equipment.

35.5% of the components do not require "to a component" trouble shooting.

Trouble shooting within a component —

90.3% of the components require diagnostic trouble shooting employing less complex test equipment and simple visual inspections.

38.7% of the components require diagnostic trouble shooting using complex test equipment.

3.2% of the components do not require "within a component" trouble shooting.

Dove

Trouble shooting to a component —

89.2% of the components employ the use of go-no-go test equipment.

8.1% of the components require diagnostic trouble shooting employing less complex test equipment and simple visual inspections.

2.7% of the components do not require "to a component" trouble shooting.

Trouble shooting within a component —

86.5% of the components require diagnostic trouble shooting employing less complex test equipment and simple visual inspections.

10.8% of the components require diagnostic trouble shooting using complex test equipment.

2.7% of the components do not require "within a component" trouble shooting.

All Missiles

Considering all components in all missiles and their associated special equipment, trouble-shooting behavior can be described as follows:

Trouble shooting to a component —

52.5% of the components require diagnostic trouble shooting employing less complex test equipment and simple visual inspections.

18.9% of the components employ the use of go-no-go test equipment.

18.0% of the components employ the use of an unprogrammed test console.

10.1% of the components require diagnostic trouble shooting using complex test equipment.

10.6% of the components do not require "to a component" trouble shooting.

Trouble shooting within a component —

67.3% of the components require diagnostic trouble shooting employing less complex test equipment and simple visual inspections.

35.5% of the components require diagnostic trouble shooting using complex test equipment.

4.6% of the components employ the use of an unprogrammed test console.

1.8% of the components do not require "within a component" trouble shooting.

Table 2

The Type of Trouble-Shooting Behavior Required for Trouble Shooting "To" and "Within" the Major Chassis of Each Missile and Its Associated Equipment

TERRIER

Missile	To	Within
1. Receiver	1,2	3b
2. Intelligence Converter	2	3b
3. Computer	2	3a
4. Servo Amplifier	1,2	3b
5. Roll System Units	2	3a
6. Programmer	2	3a
7. Electrical System	1,2	3a
8. Power Changeover System	1,2	3a
9. Booster Firing System	1,2	3a
10. Pneumatic-Hydraulic System	1,2	3a
Testing and Servicing Equipment		
11. Flight Ready Indicator	none(1)	3a
12. BuOrd Functional Test Equipment	none	3b
13. Monitoring Panel		
13.1 main chassis	3a	3a
13.2 sine wave chassis	none	3a
13.3 electronic chassis	3a	3b
14. Monitoring Panel Test Unit		
14.1 main chassis	none	3a
14.2 electronic chassis	3a	3a
15. Radar Beam Simulator		
15.1 rf chassis	3a	3a
15.2 pulse coding chassis	(secret)	--

(1) "None" means that no trouble shooting as defined here is required for a component.

Table 2 (Cont'd)

		To	Within
	TERRIER (Cont'd)		
15.3	automatic frequency control	3a	3b
15.4	FM generating and phasing chassis	3a	3b
15.5	-105-volt power supply chassis	3a	3a
15.6	low voltage power supply chassis	3a	3a
15.7	high voltage power supply chassis	3a	3a
16.	Beam Analyzer		
16.1	rf panel	3a	3b
16.2	AGC and decoder panel	3a	3b
16.3	synchroscope	none	3b
16.4	comparator panel	none	3a
16.5	reference generator	none	3a
16.6	power supply panel	none	3a
17.	Receiver Test Panel		
17.1	power supply chassis	none	3a
17.2	monitoring chassis	3a	3a
17.3	metering chassis	none	3a
18.	Hydraulic Charging Unit	none	3a
	REGULUS		
	Bi-Polar Guidance		
1.	Regulus Guidance Set		
1.1	power supply	3a	3a
1.2	receiver	3b	3b
1.3	decoder	3b	3b
1.4	program unit	3b	3b
1.5	director unit	3b	3b
1.6	encoder-transmitter	3b	3b
1.7	duplexer	3a	3a
1.8	electrical system	*	3a

*An asterisk (*) means that no adequate data was available for deciding what trouble-shooting categories were applicable to the component involved.

Table 2 (Cont'd)

REGULUS (Cont'd)	To	Within
1.9 stabilization hydraulic system	3a	3a
1.10 flight path controller	*	3b
2. Regulus Beacon		
2.1 range delay unit	3b	3b
2.2 range tracker	3b	3b
2.3 guidance delay unit	3b	3b
2.4 release unit	3a	3b
2.5 timer encoder	3b	3b
2.6 modulator-transmitter	3b	3b
2.7 receiver	3b	3b
2.8 display unit	3a	3b
2.9 power supply	3a	3b
2.10 delay unit comparator	3b	3b
3. Monitor Station		
3.1 receiver	3b	3b
3.2 decoder-director	3b	3b
3.3 loss of signal indicator	3b	3b
3.4 encoder	3b	3b
3.5 modulator-transmitter	3b	3b
3.6 delay units	3b	3b
3.7 recorder	3a	3a
3.8 power supply	3a	3a
3.9 voltage regulator unit	3a	3a
4. Regulus Guidance Set Special Test Equipment		
4.1 test pulse generator	3b	3b
4.2 test encoder	3b	3b
4.3 transmitter output monitor	3a	3b
4.4 crystal detector	3a	none
4.5 rf test load	3a	none
Radio Command Guidance		
5. Regulus Guidance Set		
5.1 radio receiving set AN/ARW-59(XN-2)	3a	3b
5.2 radio command decoder KY117(XN-2)DRW	3a	3b
5.3 throttle servo amplifier	3a	3b
5.4 throttle servo	3a	3a

Table 2 (Cont'd)

		To	Within
	REGULUS (Cont'd)		
	Trounce Guidance		
6.	KY-74/DPW Trounce Decoder	3b	3b
7.	APN-33A Trounce Transponder	3a	3b
	SPARROW		
	Missile		
1.	Tail Section	2	2, 3b
2.	Battery Unit	2	2, 3a
3.	Accumulator Unit	2	3a
4.	Hub Section Assembly	2	2, 3b
5.	Rectifier Unit	2	2, 3a
6.	Rate Gyro Unit	2	2, 3b
7.	Free Gyro Unit	2	2, 3b
8.	Servo Amplifier Unit	2	2, 3b
9.	Summing Amplifier Unit	2	2, 3b
10.	Guidance Amplifier Unit	2	2, 3b
11.	Guidance Receiver	2	2, 3b
	Testing and Servicing Equipment		
12.	Microwave Test Console		
12.1	rf head and microwave unit	3a	3b
12.2	wattmeter bridge	3a	3b
12.3	modulation monitor	3a	3b
12.4	video power supply	3a	3a
12.5	klystron power supply	3a	3a
12.6	meter panel assembly	3a	3a
13.	Video Control Console		
13.1	2500 cps reference amplifier	3a	3b
13.2	power supply #1	3a	3a
13.3	meter panel assembly	3a	3a

Table 2 (Cont'd)

	SPARROW (Cont'd)	To	Within
13.4	video meter unit assembly (General Radio model 1800A VTVM)	--(1)	--
13.5	video switching unit assembly	3a	3a
13.6	oscillator unit assembly (Hewlett-Packard 202A oscillator)	--	--
13.7	hydraulic control panel	3a	3a
14.	Recorder Console		
14.1	demodulator unit	3a	3b
14.2	Sanborn model 67-1200 four channel recorder	--	--
14.3	Sanborn model 67-1600 control panel	--	--
14.4	Sanborn model 67-300 dc amplifier	--	--
15.	System Test Console		
15.1	power supply-switching unit	3a	3a
15.2	power supply #2	3a	3a
15.3	power supply #3	3a	3a
15.4	arming and firing test unit (air)	3a	3a
15.5	power supply switching unit	3a	3a
15.6	line regulator unit (Sorenson model 3000S voltage regulator)	--	--
15.7	meter panel assembly	3a	3a
16.	Video Test Console		
16.1	quadrant dual pulse generator power supply	3a	3a
16.2	video attenuator assembly	3a	3a
16.3	quadrant dual pulse generator	3a	3b
16.4	meter panel assembly	3a	3a
16.5	pre-amp unit (Tektronix type 121 pre-amplifier)	--	--
16.6	video scope unit (Tektronix model 514D oscilloscope)	--	--
17.	Servo Test Console		
17.1	power supply #4	3a	3a
17.2	meter panel assembly	3a	3a
17.3	VTVM unit (Ballantine model 300 VTVM)	--	--

(1) The trouble shooting of standard test equipment (standard meters, oscilloscopes, etc.) is not considered here; this analysis is concerned with a missile and its special equipment.

Table 2 (Cont'd)

	SPARROW (Cont'd)	To	Within
17.4	servo scope unit (Dumont type 304 HR oscilloscope)	--	--
17.5	servo switching unit	3a	3a
17.6	monitoring unit	3a	3a
17.7	filament supply (Sorenson nobatron E-7-43)	--	--
18.	Hydraulic Console		
18.1	mechanical equipment	3a	3a
19.	Rf and Video Console		
19.1	power supply	3a	3a
19.2	video attenuator panel (Weston model 769 electronic analyzer VTVM)	--	--
19.3	VTVM panel (General Radio type 1800A VTVM)	--	--
19.4	output meter panel	3a	3a
19.5	AGC bias supply battery pack	3a	3a
20.	Component Power Supply Test Console		
20.1	autopilot timer tester	3a	3a
20.2	rectifier unit tester	3a	3a
20.3	battery unit assembly tester	3a	3a
20.4	regulator assembly tester	3a	3a
20.5	hi-potential tester	3a	3a
20.6	power supply panel	3a	3a
21.	Activated Battery Box Tester	3a	3a
22.	Hydraulic Test Bench		
22.1	power supply	3a	3a
22.2	signal synthesizer amplifier rack	3a	3b
22.3	2500 cps and dither oscillator rack	3a	3b
22.4	stroker test box	3a	3a
22.5	actuator test console		
22.5a	Industrial Control Co. dynamic analyzer model 100A spec 15A	--	--
22.5b	Ballantine model 300 VTVM	--	--
22.5c	Dumont type 304H oscilloscope	--	--
22.6	hydraulic pump and base assembly	3a	3a
22.7	arming delay tester	3a	3a
22.8	potentiometer zeroing indicator	3a	3a
23.	Gyro Test Console		
23.1	gage amplifier	3a	3b
23.2	sine drive assembly	3a	3a

Table 2 (Cont'd)

SPARROW (Cont'd)	To	Within
23.3 power supply	3a	3a
23.4 meter panel	3a	3a
23.5 free gyro control panel	3a	3a
23.6 control panel	3a	3a
23.7 rate gyro unit test assembly	3a	3a
23.7a pendulum test fixture	3a	3a
23.7b unit test selector	3a	3a
23.8 sine drive assembly	3a	3a
23.9 rate gyro/accelerometer calibrator test panel	3a	3a
24. Summing Amplifier Test Console		
24.1 summing amplifier tester	3a	3b
24.2 power supply	3a	3a
24.3 filter panel	3a	3a
24.4 meter panel		
24.4a Simpson model 260 multimeter	--	--
24.4b Ballantine model 300 VTVM	--	--
24.5 Sorenson dc power supply model 500 BB	--	--
25. Guidance Amplifier Test Console		
25.1 guidance amplifier tester	3a	3b
25.2 difference current amplifier	3a	3b
25.3 power supply	3a	3a
25.4 meter panel		
25.4a Simpson model 260 multimeter	--	--
25.4b Ballantine model 300 VTVM	--	--
26. Servo Amplifier Test Console		
26.1 servo amplifier tester	3a	3b
26.2 power supply	3a	3a
26.3 tester power supply	3a	3a
26.4 meter panel		
26.4a Simpson model 260 multimeter	--	--
26.4b General Radio type 1800A VTVM	--	--
27. Instrument Stand		
27.1 switching panel	3a	3a
27.2 Millivac type MV-73B multimeter	--	--
27.3 Ballantine ac model 300 VTVM	--	--
28. Guidance Receiver Oscilloscope Unit		
28.1 tektronix type 514D oscilloscope	--	--
28.2 tektronix type 121 pre-amplifier	--	--

Table 2 (Cont'd)

PETREL

Missile	To	Within
1. Power Supplies		
1.1 positive supplies	2	3a
1.2 negative supplies	2	3a
2. Transmitter and Receiver Rf Sections	2, 3a	3a, 3b
3. AFC Unit	2, 3b	3a, 3b
4. If Amplifier	2, 3a	3a, 3b
5. Range Unit	2, 3a	3a, 3b
6. Yaw Unit	2, 3a	3a, 3b
7. Antenna Stabilization	2, 3a	3a, 3b
8. Auto Pilot	2, 3a	3a, 3b
9. Control Surface Actuators	2, 3a	3a
Control Monitor Group		
10. Pulse Generator	2, 3a	3a, 3b
11. Power Supply PP 505	2, 3a	3a
12. Control Indicator Assembly	2, 3a	3a
13. High Voltage Power Supply	2, 3a	3a
14. Control Monitor Group Unit	2, 3a	3a
15. Fine Range Unit	2, 3a	3a, 3b
16. Target Presentation Unit	2, 3a	3a, 3b
17. Engine Control Unit	2, 3a	3a
Test Set AN/DSM-1		
18. Tube Tester (Hickock TU-7/U)	---	---
19. Detonator Test Set (ohmmeter)	---	---
20. Inverter Box	none	3a
21. Magnetron Test Unit	none	3b
22. Missile External Load Box	none	3a

Table 2 (Cont'd)

		To	Within
	PETREL (Cont'd)		
23.	Generator Adjusting Device	none	none
24.	Multimeter (Weston TS-352 A/U)	---	---
25.	Crystal Test Set (TS-268D)	---	---
26.	Ac Dc VTVM (ME-25/V)	---	---
27.	Autopilot Test Set	none	3a
28.	Servo Amplifier Test Adaptor	none	3a
29.	Monitor Test Unit	none	3a
30.	Monitor Adaptor Unit	none	3a
31.	Remote Meter Box	none	3a
32.	Power Distribution and Control Panel	none	3a
33.	Signal Generator (AN/UPM-43)	---	---
34.	Oscilloscope (256-D)	---	---
35.	Control Monitor Group Unit	2, 3a	3a
36.	Monitor Power Unit (power supply PP505)	2, 3a	3a
37.	Spectrum Analyzer (TS-148/UP)	---	---
38.	Tuned Cavity	none	3a
	DOVE		
	Missile		
1.	Nose Assembly		
1.1	hard tube timer	1	3a
1.2	voltage regulator	1	3a
1.3	oscillator power supply	1	3a
1.4	eye gyro drive relay	1	3a
1.5	nozzle assembly	1	3b
1.6	signal amplifier	1	3b
1.7	torque motor drive	1	3b
1.8	computer	1	3b
1.9	nose breakaway switch	1	3a
1.10	actuator valve assembly (solenoid)	1	3a

Table 2 (Cont'd)

DOVE (Cont'd)	To	Within
1.11 high pressure pneumatic assembly	1	3a
1.12 pneumatic actuator drive	1	3a
1.13 nose fairing assembly	1	3a
1.14 base plate assembly	1	3a
1.15 stabilizer	1	3a
1.16 uncaging mechanism	1	3a
2. Tail Assembly		
2.1 hub and propeller assembly	3a	3a
2.2 generator	1	3a
2.3 generator voltage regulator assembly	1	3a
2.4 undervoltage relay	1	3a
2.5 tail transfer relay	1	3a
2.6 dynamotor	1	3a
2.7 dynamotor voltage regulator assembly	1	3a
2.8 fuse arming assembly	3a	3a
2.9 fuse assembly	none	none
2.10 roll control gyro	1	3a
2.11 bulkhead and bottle assembly	1	3a
2.12 actuator valve assembly (solenoid)	1	3a
2.13 actuator-tail pneumatics	1	3a
2.14 tail skins, tail fairing and nose skirt assembly	3a	3a
Testing and Servicing Equipment		
3. Preflight Checkout Console; Main Control Unit		
3.1 480-volt dc power supply	1	3a
3.2 30-volt dc power supply	1	3a
3.3 250-volt dc power supplies "A", "B", and "C"	1	3a
3.4 timer chassis (chassis number 1)	1	3a
3.5 test circuits chassis (chassis number 2)	1	3a
4. Preflight Checkout Console; Nose Unit	1	3a
5. Preflight Checkout Console; Tail Unit	1	3a

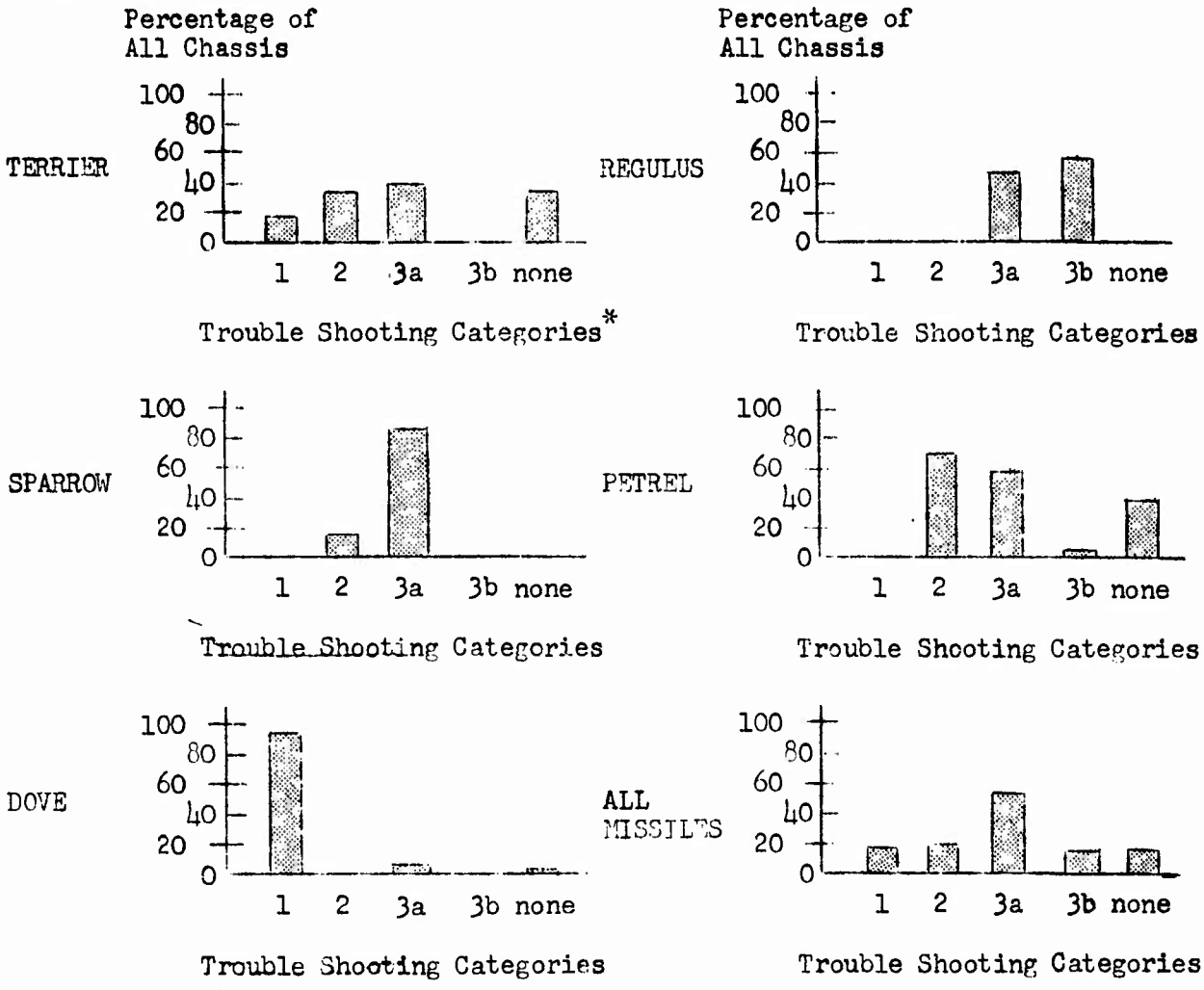


Fig. 2a. The Percentage of Missile and Associated Equipment Chassis Requiring the Various Categories of Trouble-Shooting Behavior: Trouble Shooting to a Chassis.

*Key to Trouble-Shooting Categories:

1. Using Go-No-Go Test Equipment
2. Using an Unprogrammed Test Console
3a. Using Standard Equipment for Diagnostic Trouble Shooting: Using less complex standard test equipment and making simple visual inspections
3b. Using Standard Equipment for Diagnostic Trouble Shooting: Using complex standard test equipment

none. (explanation in text)

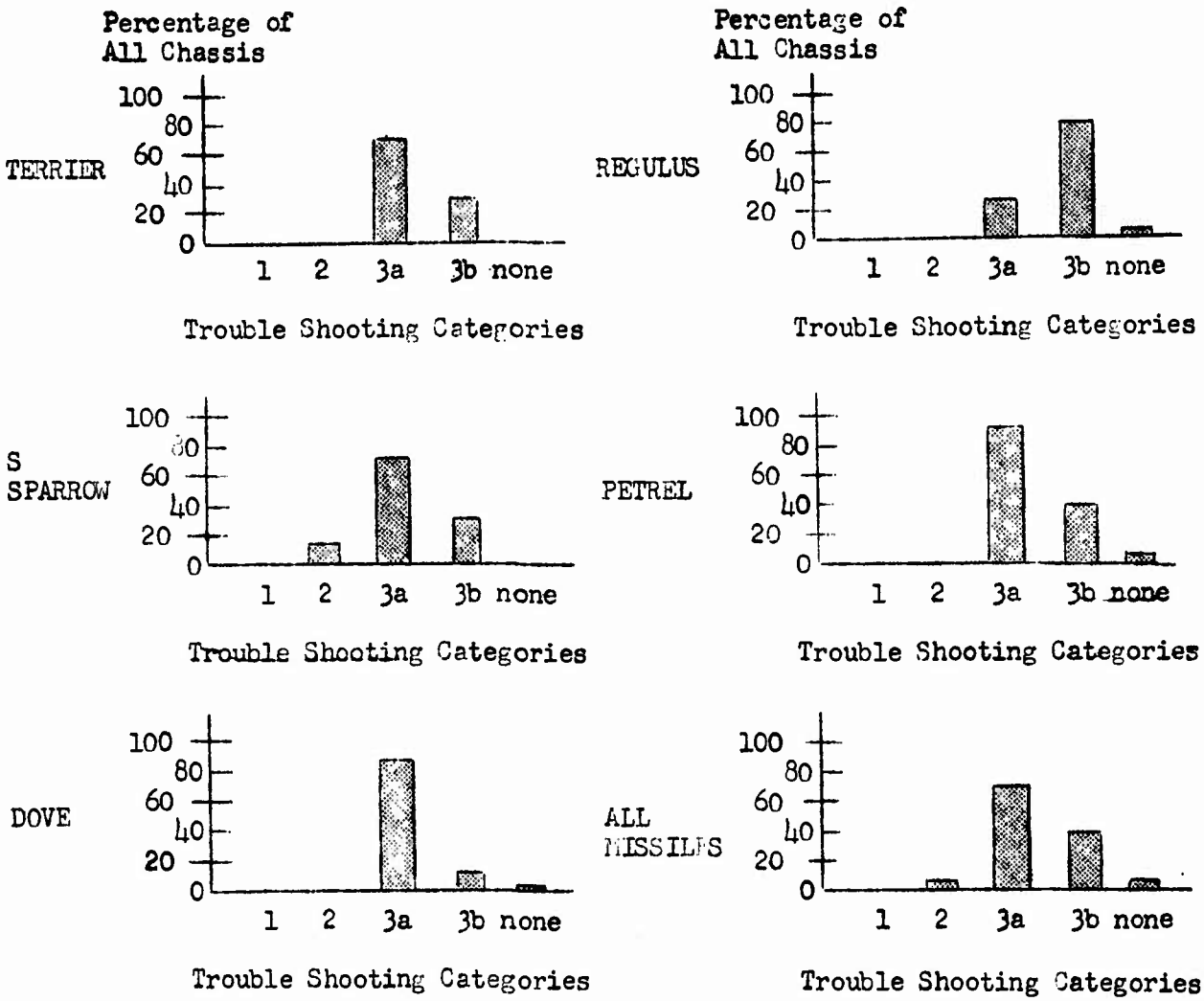


Fig. 2b. The Percentage of Missile and Associated Equipment Chassis Requiring the Various Categories of Trouble-Shooting Behavior: Trouble Shooting within a Chassis.

*Key to Trouble Shooting Categories:

1. Using Go-No-Go Test Equipment
2. Using an Unprogrammed Test Console
3a. Using Standard Equipment for Diagnostic Trouble Shooting: Using less complex standard test equipment and making simple visual inspections
3b. Using Standard Equipment for Diagnostic Trouble Shooting: Using complex standard test equipment
none. (explanation in text)

Knowledge of Missile Operation

Table 3 presents a comparison of the knowledge or theory of missile operation associated with the five missiles under consideration. The development of this table is described in Chapter 1. This table offers a comparison of the common and unique aspects of knowledge of operation of different types of guided missiles in terms of functional elements and should be of particular value in establishing theory aspects of a basic curriculum for the guided missileman. The specific relationships between aspects of knowledge of missile operation and proficiency in trouble shooting, i.e., just how much theory is essential for proficiency in trouble shooting is an important problem for future research. However, preliminary work with an experimental guided missile proficiency battery shows a high relationship between knowledge of operation and trouble-shooting proficiency.[1]

In the detailed construction of Table 3, the following procedures were adopted:

1. Only entire vacuum tube stages or groups of components of comparable complexity are listed or described for any functional element.

2. Reference tube numbers from maintenance manuals and manufacturers' schematic diagrams are employed to identify the stages listed or described.

3. The primary purpose of the chart is to indicate with respect to the five missiles the uniqueness or similarity of certain missile circuits. Coupling circuits such as coupling condensers, transformers, and cathode followers are not listed. Such circuits are generally present in all electronic missile guidance and control systems and do not help to discriminate between the similar and unique aspects of missile functioning. For this same reason temperature control and electrical overload protection circuits are not listed.

4. When two or more parallel channels exist, components are listed only once.

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[1] Glaser, R.; Hahn, J.; and Phillips, J.C. "An Analysis of Tests of Proficiency for Guided Missile Personnel: I. Multiple-Choice Tests, II. The Trouble-Shooting Board," American Institute for Research, August 1954.

5. When overlap equipment, i.e., equipment not considered as part of the duties of a missileman rating, is used in a missile to perform a particular function, the equipment name is given and marked with an asterisk (*). This indicates aspects of missile functioning which may not be the concern of the guided missileman.

In Table 3 the five missiles are listed along the horizontal axis and the functional elements are listed along the vertical axis; the cells of the table contain the specific circuitry by which the particular function (of the functional element) is performed in a missile. The functional elements are listed so that those elements present in all five missiles are at the beginning of the table and the functional elements unique to one missile are listed at the end of the table. This latter arrangement makes evident the following:

The functional elements <u>common to all five missiles</u> are:

AGC
Pulse time-sequence analyzers (coincidence and range sensing circuits)
Pulse amplifiers
Guidance switching and/or distribution circuits
Control surface transducers
Orientation sensing devices
Power supply
Power sources
Terminal guidance and/or detonation control

The functional elements common to four missiles, Terrier, Regulus, Sparrow and Petrel, are:

Antenna receiving
Transmit-receive antenna switches or antenna shield
Waveguide
Detector
Error signal limiters
Servo amplifiers and drivers
Error system rate corrector and amplifiers

The functional elements <u>common to three missiles</u> are:

Mixer
Local oscillator

If amplifier
Pulse-detector amplifier units
Destruct circuits
Rate sensing device
Altitude compensation and control

The functional elements common to two missiles are:

Antenna transmitting
If preamplifier
AFC
FM detector
Beam-divergence compensation
Carrier modulators, demodulators and buffers
Resolving circuits
Dither oscillator
Af and dc amplifier with passive summing inputs
Pulse modulator and transmitter
Target scanning systems in missile

The functional elements unique to one missile are:

Rf preselector
Frequency multipliers
FM limiter
Squelch circuits
Timing signal generator
Phase and amplitude sensitive demodulators and driver
Integral error circuit
Pulse time code generator
Gyro processing system
Electronic pulse counters and count difference detectors

Considering surface-launched and air-launched missiles as two groups, the surface-launched missiles, Terrier and Regulus, have 23 of the 44 functional elements in common. Of the air-launched missiles, Sparrow, Petrel and Dove have nine out of the 44 functional elements in common, and Sparrow and Petrel have 16 out of the 44 in common.

Table 3

A Comparison of Major Functional Elements of Missile Operation for Five Guided Missiles

Functional Elements	Missile	
	Terrier	Regulus
1. AGC	Triode amplifier V14	Trounce: ------ R/C: V 502 diode rectifier Bi-Polar: ------
2. Pulse time-sequence analyzers (coincidence and range sensing circuits)	SECRET	Trounce: Triode trigger amplifier, V-1A, B. Blocking oscillator, V-2, V-3, 9a, 10a, 11a, 12a, 13a Delay lines Coincidence tubes V-4, 5, 6, 7, 8 PRF discriminators, V-14a, 14b R/C: ------ Bi-Polar: Cathode coupled mono-stable multivibrators, V2701, 8 Diode dc restorer, V2702A Shock excited oscillator V2703 Diode limiters V270H A, B Blocking oscillator V2707A Triode Amplifier V2707B R-C, Diode bridge type phase detector, V2706A, B C2705A, B Cathode follower vacuum tube bridge V2705A, B Pentode coincidence tube V2401, 3, 5 Blocking oscillator V2402B, 4A, 4B Crystal diode clippers CR2401, 2, 3, 4, 5 Delay line DL 2401

Table 3

A Comparison of Major Functional Elements of Missile Operation for Five Guided Missiles

Missile		
Sparrow	Petrel	Dove
Passive summing network	Triode amplifier V909	Duo-diode signal comparator, filter, and potentiometer for adjustable delay V208, 308
Pentode coincidence tubes V2809 Delay line DL 2801 V2804 Pentode pulse stretcher	Triode dc amplifier V811 16 Suppressor modulated pentodes V905, 10, 12 Tank circuits Z802, 803 Dc amplifiers and integrating condenser V808, 9, 10 Diode clipper V804A; triode amplifier and differentiating circuit V812	Pulse discriminator diodes, V501, 601 Cross channel gating multivibrators, V503, 603 Gated multi-vibrators, V505, 6; 605, 6

Table 3 (Cont'd)

Functional Elements	Missile	
	Terrier	Regulus
3. Pulse amplifiers	Cathode follower V8 Pentode amplifier w/diode damping V 7 (video amplifier) Pulse stretcher, cathode follower V9	Trounce: V-201-7 Pentode amplifier with shunt peaking Triode cathode follower V202 (video amplifier) R/C: Triode V301A (video amplifier) Bi-Polar: Pentode amplifier V2306 Cathode follower V2307 (video amplifier)
4. Guidance Switching and/or distribution circuits	Motor driven cylindrical potentiometers, and can operated microswitches Long time constant R-C circuits Pentode relay tube V206	Trounce: ------ R/C: Band bass carrier filters Bi-Polar: ------
5. Control surface transducers	Solenoid actuated hydraulic valves Wing actuator Servo feedback potentiometer	Trounce: Autopilot Throttle-Servo (two phase)* Other relays with hydraulic and pneumatic solenoid valves* R/C: (Same as Trounce) Bi-Polar: (Same as Trounce)

Table 3 (Cont'd)

Missile		
Sparrow	Petrel	Dove
Triode-pre-amplifier V2901 Pentode with and without shunt peaking V2801, 2, 3, 5 Triode with shunt peaking V2804 Diode grid unblocking circuits V2819 Triode regenerative amplifier V2806 (video amplifier)	R-C coupled pentodes V901, 3 (video amplifier)	Triode V202, 5, 302, 5 and pentode V203, 4; V303, 4 (audio amplifier)
R-C timed Thyratron relay control tube V2403	Thyratron switch tubes V2503, 4, 5 Relays K2501, 2, 3 Cathode coupled monostable multi-vibrator V2509 Triode gated discharge tube V2506B Diode-condenser counting circuit V2507	R-C timers, grid controlled hard tube Relay amplifiers V1001, 1002, 1003
Solenoid valve strokers E3103 Hydraulic servo valves Hydraulic cylinder-wing actuator Servo feedback potentiometer	Motor driven with electric servo actuated clutches	Pneumatically operated nose deflectors and tail ailerons Solenoid operated valve controls 150 psi compressed dry nitrogen to operate aileron actuating piston Solenoid operated valve controls 225 psi compressed dry nitrogen to operate nose deflector actuating pistons

Table 3 (Cont'd)

Functional Elements	Missile	
	Terrier	Regulus
6. Orientation sensing devices	Roll free gyro Ships roll corrector synchro	Trounce: Autopilot* T/C: Autopilot* Bi-Polar: Autopilot*
7. Power supply	Three phase induction alternator Three phase and single phase rectified supplies V101, 2, 3, 4, 5, 6, 7, 8 L-C power supply filters CH 101, C101, etc. Series voltage regulators (and associated amplifiers and VR tubes) V202, 3, 4, 7, 8 Low voltage full wave supply	Trounce: Dynamotor, VR tubes V107, 8, 203, 4 R/C: Dynamotor, ½ wave diode rectifier Bi-Polar: Three phase half wave rectified supply with thyratron rectifiers V2101, 2, 3 Series voltage regulators (and associated amplifiers and VR tubes) V2404, 5, 6 Single phase half wave rectified supply V2108 VR tube regulated supply V2110, 11 Inverter, 115V, three phase 400 cps output
8. Power sources	Air flask Piston type air driven hydraulic pump (autopac) Hydraulic sump Hydraulic motor	Trounce: 28v dc generator runs off engine 24v and 6v wet batteries 30v dry cell source for destruct circuits R/C: (Same as Trounce) Bi-Polar: (Same as Trounce)

Table 3 (Cont'd)

Missile		
Sparrow	Petrel	Dove
Roll free gyro Pitch-yaw free gyro	Antenna free gyro Vertical free gyro	Roll free gyro
Full wave rectified supplies T2401, V2401, 2, 3 4, 5, 6 L-C power supply filters Z2401, etc. Series voltage regulators (and associated amplifiers and VR tubes) V2407; V2513, 14; V2201, 3, 4, etc. Vibrator-inverter E2201 Wet cell Z2201	Rectifiers - three phase, full wave V713, 14, 15; V701, 6, 10; V401, 4, 7 Series voltage regulators (and associated amplifiers and VR tubes) V402, 5; V702	22v to 480v dynamotor with carbon pile regulator 5000 cps blocking oscillator with voltage doubler rectifier and filter CR1101, 2, 3, 4 Series voltage regulators (and associated amplifiers and VR tubes) V701, 2, 3
Wet cell Z2201 Hydraulic accumulator (chassis 37)	400 cps three phase generator runs off engine	Nitrogen flasks, air-screw driven dc shunt generator with carbon pile voltage regulator

Table 3 (Cont'd)

Functional Elements	Missile	
	Terrier	Regulus
9. Terminal guidance and/or detonation control	Guidance unchanged, proximity fuze	Trounce: Splash system terminal dive control R/C: Interim system dive path controller, no fuze information Bi-Polar: No fuze information
10. Antenna receiving	Open end wave guide, plastic matching section	Trounce: (Secret) R/C: Antenna AT-335/ARW Bi-Polar: Quarter-wave dipole radiator
11. Transmit-receive antenna switches or antenna shield	Metal cap	Trounce: Duplexer R/C: ------ Bi-Polar: TR tube V2002, ATR tube V2003
12. Waveguide	Yes	Trounce: Yes R/C: No Bi-Polar: No
13. Detector	Crystal diode CR2	Trounce: Diode V201-6 R/C: Crystal diode CR401 Bi-Polar: Diode V2308

Table 3 (Cont'd)

Missile		
Sparrow	Petrel	Dove
Guidance unchanged, proximity fuze	Air frame jettisoned and missile becomes a torpedo	Guidance unchanged, impact detonator
Open end waveguide, plastic matching section	Parabolic dish	------
TR tube V2941	Switch tubes V103, 4	------
Yes	Yes	No
Crystal diode CR2941	Diode V310A	------

Table 3 (Cont'd)

Functional Elements	Missile	
	Terrier	Regulus
14. Error signal limiters	Double diode limiters V302, 304	Trounce: ------ R/C: Triode grid limiting amplifier V305A Coupling neon tube V304 Diode limiters V305B, 306A Bi-Polar: Biased diodes (flight path controller) V102A, 102B
15. Servo amplifiers and drivers	Cathode coupled difference amplifier V102 Push-pull pentode power servo amplifiers V101, 103	Trounce: ------ R/C: Push-pull ac triodes Bi-Polar: ------
16. Error system rate corrector and amplifiers	R-C rate network Compensated dc amplifier V301	Trounce: ------ R/C: Rate pick-off synchro Bi-Polar: R-C rate network (flight path controller)
17. Mixer	Crystal IN23B	Trounce: Crystal IN21B R/C: V102 pentode Bi-Polar: Crystal CR2201
18. Local oscillator	Klystron K302	Trounce: Klystron V102 R/C: V402 crystal controlled Bi-Polar: Lighthouse V2312

Table 3 (Cont'd)

Missile		
Sparrow	Petrel	Dove
Cathode follower-grounded grid triode amplifier V2501, 2, 5, 6, 11, 12	V1501 diode limiter V1002 diode limiter	------
Triode dc push-pull cathode follower V2605, 6 Low pass L-C filter L2601, C2603 Pentode power servo amplifiers V2607, 8	Dc amplifier V209 (antenna servo) Triode push-pull amplifiers V1201 Dc pentodes V1203, 4	------
Passive lag network R-C 2312, 22, etc. Triode push-pull lead amplifier V2304, 5, 6, 7	R-C network in autopilot	------
------	Crystal, CR101	------
------	Klystron V101	------

Table 3 (Cont'd)

Functional Elements	Missile	
	Terrier	Regulus
19. If amplifier	Stagger tuned, band pass pentode amplifier V1, 2, 3, 4, 5, 6	Trounce: Pentode shunt peaked V201, 2, 3, 4, 5 R/C: V201, 8, 9 tunable Pentode if amplifiers; 2nd if V205, 206; 2nd if crystal controlled oscillator; V301, 2, 3, 4 pentode amplifiers; V204 pentode mixer Bi-Polar: Stagger tuned, band pass pentode amplifier V2301, 2, 3, 4, 5
20. Pulse detector-amplifier units	Box-car detector V1329, V28; CR9310, 11	Trounce: ------ R/C: V301A, 301B, 302B triode pulse amplifiers V302A diode detector V303 neon-bulb coupling tube Bi-Polar: ------
21. Destruct circuits	Tuned circuit L108, C143 Longtime constant R-C circuits C144, R149 Triode relay tube V25	Trounce: (Secret) R/C: V504 squelch tube relay timers, solenoid valves Bi-Polar: ------
22. Rate sensing device	Roll rate gyro	Trounce: ------ R/C: ------ Bi-Polar: ------
23. Altitude compensation and control	Potentiometers mechanically linked to slyphon bellows, $(1/P_s)$	Trounce: Autopilot* R/C: Autopilot* Bi-Polar: Autopilot*

Table 3 (Cont'd)

Missile		
Sparrow	Petrel	Dove
------	Stagger tuned band pass pentode if amplifier V303, 4, 5, 6, 7, 8, 9; V501, 2 3	------
------	------	Phase inverters V203, 6 Summing cathode followers V207, 307
Summing thyratron switch tube V2303	------	------
Yaw rate gyro Roll rate gyro Pitch rate gyro Linear accelerometers, L2501, 2	------	Roll rate gyro
------	Radio altimeter	------

Table 3 (Cont'd)

Functional Elements	Missile	
	Terrier	Regulus
24. Antenna transmitting	------	Trounce: (Secret) R/C: Antenna AT-335/ARW Bi-Polar: Quarter-wave dipole radiator
25. If preamplifier	------	Trounce: ------ R/C: Grounded grid triode V2204 Pentode amplifier V2203 Resonant decoupling Filter Z2205 Bi-Polar: -------
26. AFC	Triode amplifier V14 Tuned 400 cps pass filter Ring demodulators CR201, 2, 3, 4, 5, 6, 7, 8	Trounce: ------- R/C: ------ Bi-Polar: ------
27. FM dectector	Triggered blocking oscillator V20 Pentode pulse stretcher amplifier V21 Weiss discriminator V22, 23	Trounce: ------ R/C: V307, 8 Foster Seeley discriminator Bi-Polar: ------
28. Beam-divergence compensation	Linear potentiometer, motor operated cylindrical type $f_1(t)$	Trounce: ------ R/C: ------ Bi-Polar: ------

Table 3 (Cont'd)

Missile		
Sparrow	Petrel	Dove
------	Parabolic dish	------
------	Cascode amplifier, V301, 2	------
------	Mixer V501 Discriminator V503 Phantastron V506, 7	------
------	------	------
Long time constant network and relay	------	------

Table 3 (Cont'd)

Functional Elements	Missile	
	Terrier	Regulus
29. Carrier modulators, demodulators and buffers	------	Trounce: Amplifier R/C: Magnetic V308A and T301, 102 push-pull triodes Bi-Polar: 400 cps "chopper" D101
30. Resolving circuits	Triode amplifiers V402 R-C phase shifting networks C404, 405, R411, 412	Trounce: ------ R/C: ------ Bi-Polar: ------
31. Dither oscillator	------	Trounce: Autopilot* R/C: Autopilot* Bi-Polar: Autopilot*
32. Af and dc amplifier with passive suming inputs	------	Trounce: ------ R/C: ------ Bi-Polar: ------
33. Pulse modulator and transmitter	------	Trounce: Magnetron oscillator V103 Pulsing triode V101 Gating blocking oscillator V106 R/C: ------
(Cont'd)	(Cont'd)	(Cont'd)

Table 3 (Cont'd)

Missile		
Sparrow	Petrel	Dove
Tuned plate af oscillator V2301, 2302 Balanced push-pull pentode modulators V2308, 9 Pentode push-pull af amplifier V2310, 11 Commutated bridge rectifier demodulator V2603, 4	------	------
Gyro positioned resolver trans B3203 Triode summing amplifiers V2301, 2, 3	------	------
Push-pull tuned plate af oscillator V2650, 1, 2	------	------
Pentode and triode af feedback amplifiers V2503, 4, 9, 10 Cathode coupled twin triode, af difference amplifier V2601, 2	V1001, 1003, 4, 1504, 1506 dc pentode grid summing amplifiers	------
------ (Cont'd)	Magnetron oscillator V102 Multi-vibrator V802 High voltage rectifier V601, 3 (Cont'd)	------ (Cont'd)

Table 3 (Cont'd)

Functional Elements	Missile	
	Terrier	Regulus
33. (Cont'd)	(Cont'd)	(Cont'd) Bi-Polar: Thyratron switch tubes V2609, 12 Line type pulse forming network Z2602, 3 and associated charging and shunt diodes V2607, 8, 10, 11 Magnetron S band transmitter V2616 Half wave voltage doubler rectifier V2613, 14 Saturable reactor regulator L2601
34. Target scanning systems in missile	------	Trounce: ------ R/C: ------ Bi-Polar: ------
35. Rf preselector	------	Trounce: ------ R/C: V101 pentode Bi-Polar: Tuned cavity Z2221
36. Frequency multipliers	------	Trounce: ------ R/C: Pentodes V403 Triode V402 Bi-Polar: ------

Table 3 (Cont'd)

Missile		
Sparrow	Petrel	Dove
(Cont'd)	(Cont'd)	(Cont'd)
------	Bi-stable multi-vibrator V915 Commutated diode V907 Commutated thyratron V911, 12, 13	Gear driven reflecting mirror, oriented by free running gyro. Projects target image upon bolometer flakes. Nozzle amplifiers V201, 301
------	------	------
------	------	------

Table 3 (Cont'd)

Functional Elements	Missile	
	Terrier	Regulus
37. FM limiter	------	Trounce: ------ R/C: V305, 6 pentode Bi-Polar: ------
38. Squelch circuits	------	Trounce: ------ R/C: ------ Bi-Polar: ------
39. Timing signal generator	------	Trounce: ------ R/C: ------ Bi-Polar: ------
40. Phase and amplitude sensitive demodulators and driver	Cathode coupled phase inverters V404, 407 Ring demodulator V403 Triode amplifier V205 Ring demodulator V204	Trounce: ------ R/C: ------ Bi-Polar: ------
41. Integral error circuit	Cathode coupled triode amplifiers V303, and cathode follower V306 connected as regenerative amplifier with long time constant feedback circuit	Trounce: ------ R/C: ------ Bi-Polar: ------
42. Pulse time code generator	------	Trounce: ------ R/C: ------ Bi-Polar: Triggered blocking oscillators V2602, 5 Cathode followers V2303, 4

Table 3 (Cont'd)

Missile		
Sparrow	Petrel	Dove
------	------	------
------	------	------
------	Phase shift oscillator V801	------
------	-------	------
------	------	------
------	------	------

Table 3 (Cont'd)

Functional Elements	Missile	
	Terrier	Regulus
43. Gyro precessing system	------	Trounce: ------ R/C: ------ Bi-Polar: ------
44. Electronic pulse counters and count difference detectors	------	Trounce: ------ R/C: ------ Bi-Polar: ------

Table 3 (Cont'd)

Missile		
Sparrow	Petrel	Dove
------	------	Torque motor drive for precessing gyro to follow target V507, 8, 9; V607, 8, 9
------	------	Three stage E-J counter V805, 6, 7; 905, 6, 7 Back count triggers V802, 3, 4; 902, 3, 4 Differential detector V808, 908

Handling, Assembly and Servicing

In accordance with the procedure described in Chapter 1, the results of the analysis of handling, assembly and servicing tasks are presented in Table 4 and more graphically in Figure 3. Table 4 and Figure 3 show the percentage of all behavior statements for a particular missile that constitute particular handling, assembly and servicing behavioral categories; the last line in Table 4 shows the number of behavior statements written for each missile, 49 for Terrier, 47 for Regulus, 48 for Sparrow, 32 for Petrel, and 24 for Dove.

In Figure 3 the behavioral categories are listed in order of their average rank order of frequency of occurrence considering all missiles together. The first category, "Assembling and disassembling missiles by hand and with hand tools," is on the average for the five missiles the most frequently used behavioral category, i.e., on the average the highest percentage of behavior statements for each missile have been classified in this category. Detailed lists of the handling, assembly and servicing tasks and associated behavior statements for each missile are presented in Appendix D accompanying this report. The behavior statements for all missiles that are included in each of the particular behavioral categories are presented in Appendix E.

Inspection of the results shown in Table 4 and Figure 3 show that, in general, the behaviors required for handling, assembly and servicing activities are similar for the five missiles. The behavior statements written for each missile fall into most all of the 12 behavioral categories; although there is variation among the missiles with respect to the relative proportion of the behavior statements that constitute a behavioral category. Certain aspects of the data should be mentioned. Since Petrel has no hydraulic system, this missile has no behavior statements classified in categories 4 and 9 in Figure 3 which are concerned with air and hydraulic system

servicing. Terrier and Dove have no behavior statements in category 12, "Leveling, positioning and measuring to align missile air surfaces and rockets"; the performance of behavior of this kind may be of minor importance because of the construction of these two missiles, or the procedures for accomplishing this have not been spelled out in the manuals available for these missiles. Dove has no behavior statements in category 8 which is concerned with manual manipulation of missile components; obviously such behavior is required for Dove but has not been "firmed up" and spelled out in the preliminary manuals and other materials now available.

In summary, it appears that the underlying behaviors required for handling, assembly and servicing activities are much the same for all five missiles under consideration. A general curriculum might be concerned with the use of the kinds of tools employed and the procedures employed in these activities. Since, however, handling and assembly procedures may be quite specific to particular installations and, for the most part, consist of behaviors that can be learned in a short period of time, detailed practice and the development of specific skill may best be a matter of on-the-job training.

Table 4

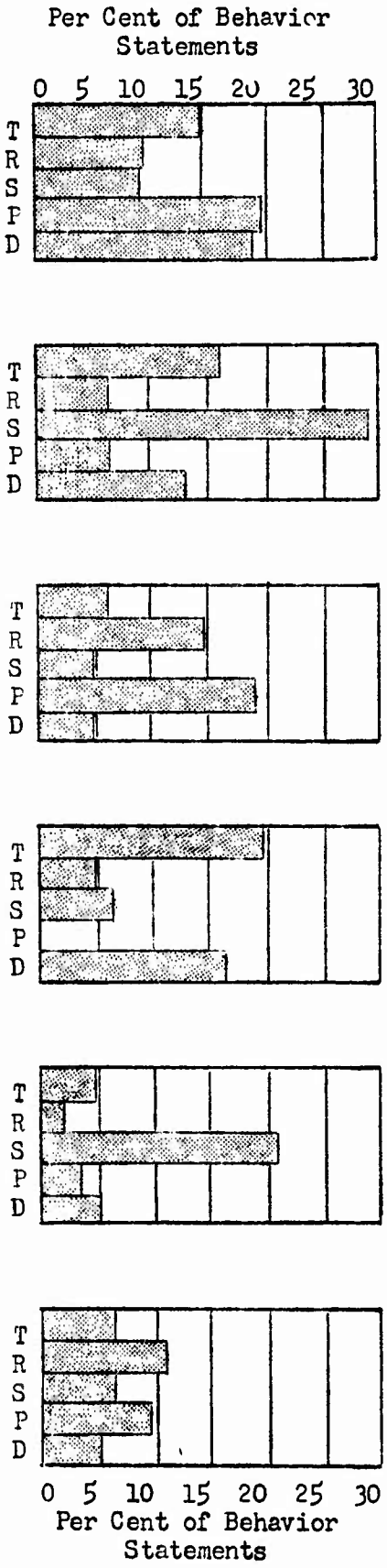
Percentage of Behavior Statements in Each
Handling, Assembly and Servicing Category for Each Missile

	Terrier	Regulus	Sparrow	Petrel	Dove
Assembling and disassembling missiles by hand and with hand tools.	16.3%	10.6%	10.4%	21.9%	20.8%
Attaching, securing, and detaching to lift, haul, and secure missiles and associated equipment.	6.1	10.6	6.2	9.4	4.2
Checking and inspecting during missile transfer, assembly, and servicing.	16.3	6.4	29.2	6.2	12.5
Connecting and disconnecting high pressure air and hydraulic lines during missile air and hydraulic servicing.	8.2	4.3	4.2	—	8.3
Connecting and installing electrical wires, cables and parts during missile transfer, assembly, and servicing.	6.1	10.6	4.2	9.4	4.2
Leveling, positioning, and measuring to align missile air surfaces and rockets.	—	4.3	2.1	6.2	—
Locking-unlocking, assembling-disassemblying, packing-unpacking and pressurizing-bleeding to remove and replace missiles and missile parts in containers.	12.2	12.8	2.1	3.1	16.7
Lubricating, cleaning, and battery maintenance during missile assembly and servicing	4.1	2.1	20.8	3.1	4.2

Table 4 (Cont'd)

	Terrier	Regulus	Sparrow	Petrel	Dove
Manually pushing, pulling, lifting, carrying, and manipulating to transport, position, and stow missiles, missile parts, and associated equipment.	4.1%	14.9%	6.2%	15.6%	--%
Operating motor vehicles and electrically powered equipment to lift, position, transport, and stow missiles, missile parts, and associated equipment.	6.1	14.9	4.2	18.8	4.2
Reading electrical and mechanical diagrams to determine missile assembly procedures.	2.0	4.3	4.2	6.2	8.3
Setting valves and switches, and reading gages during missile air and hydraulic servicing.	18.4	4.3	6.2	—	16.7
Total Number of Behavioral Statements	49	47	48	32	24

Fig. 3. Percentage of Behavior Statements in Each Handling, Assembly and Servicing Category for Each Missile.*



1. Assembling and disassembling missiles by hand and with hand tools.

2. Checking and inspecting during missile transfer, assembly, and servicing.

3. Operating motor vehicles and electrically powered equipment to lift, position, transport, and stow missiles, missile parts and associated equipment

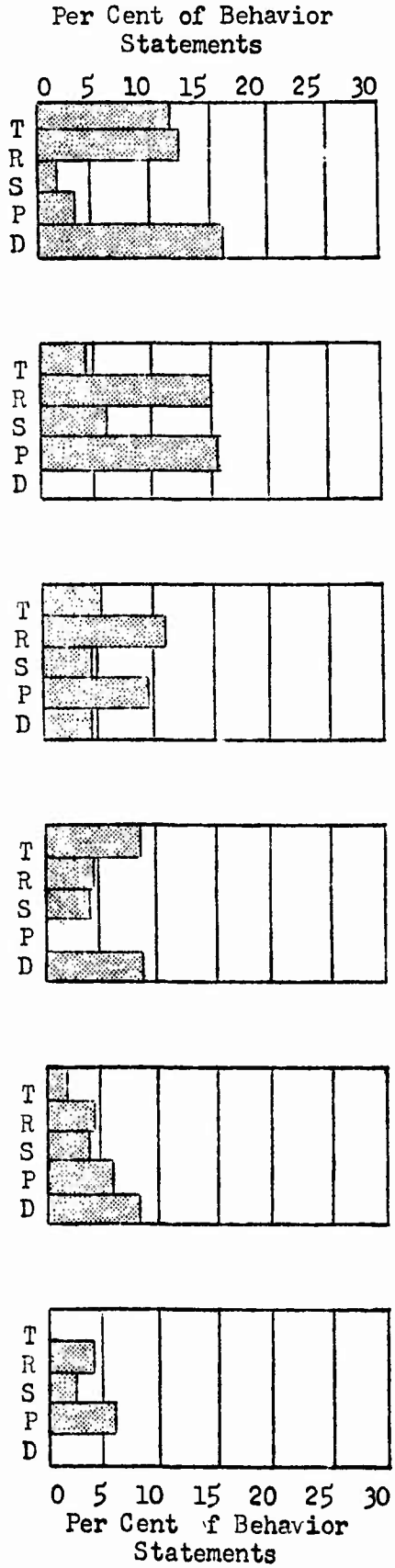
4. Setting valves and switches, and reading gages during missile air and hydraulic servicing.

5. Lubricating, cleaning, and battery maintenance during missile assembly and servicing.

6. Attaching, securing, and detaching to lift, haul, and secure missiles and associated equipment.

*Key: T=Terrier, R=Regulus
S=Sparrow, P=Petrel
D=Dove

Fig. 3. (Cont'd)


Per Cent of Behavior Statements
0 5 10 15 20 25 30
T
R
S
P
D
7. Locking-unlocking, assembling-disassembling, packing-unpacking and pressurizing-bleeding to remove and replace missiles and missile parts in containers.
8. Manually pushing, pulling, lifting, carrying, and manipulating to transport, position, and stow missiles, missile parts, and associated equipment.
9. Connecting and installing electrical wires, cables and parts during missile transfer, assembly, and servicing.
10. Connecting and disconnecting high pressure air and hydraulic lines during missile air and hydraulic servicing.
11. Reading electrical and mechanical diagrams to determine missile assembly procedures.
12. Leveling, positioning, and measuring to align missile air surfaces and rockets.
0 5 10 15 20 25 30
Per Cent of Behavior Statements

Summary

This chapter has presented the results of a comparative analysis of missileman tasks for five guided missiles. Tables and graphs have shown an analysis and comparison of the behaviors involved in testing and adjustment procedures; trouble shooting; and handling, assembly and servicing activities. In interpreting these results the following should be kept in mind:

1. The tasks covered are those with which a technician in the guided missileman rating is most likely to be concerned. These tasks are concerned with the missile and its associated test equipment for all missiles except Regulus where it seems feasible to assign to the guided missileman assigned to submarine duty sure tasks concerned with external guidance equipment. A detailed description of the major equipments for each missile which appear to be the responsibility of the guided missileman rating is given in Appendix A.

2. As a function of the developmental stage of the weapon, available information for any particular missile is more or less complete; missiles and equipment within missiles differ in this respect as is indicated in this report.

CHAPTER 3

SUMMARY AND RESEARCH RECOMMENDATIONS

A detailed statement of the skills and knowledges required by guided missilemen for the performance of the tasks associated with particular missiles and groups of missiles is presented in Chapter 2. Specifications of these skills and knowledges provide the basic data for the development and refinement of: a rating structure, rating qualifications examinations, selection procedures, training programs and proficiency measurement techniques. The nature of this report is such that a complete picture of the comparative analysis of missileman tasks is best obtained by reading the preceding chapters. Job analysis methodology is an important outcome of this research effort, and description of the methods employed in the present analysis is given in Chapter 1. The specific results of the analysis are given in Chapter 2 and in detailed appendices. For the purposes of brief summary, however, this chapter reviews in concise fashion the skills and knowledges of guided missileman ratings that are general to the five missiles studied; these missiles are Terrier, Regulus, Sparrow I, Petrel and Dove.

In addition, this chapter presents recommendations for future research activities that are indicated on the basis of the work,performed thus far in the guided missile personnel research program.

General Skills and Knowledges of Guided Missileman Ratings

Testing and Adjustment

In the performance of testing and adjustment procedures, the major categories of behaviors that are common to at least four of

the five missiles studied are the following:

Adjusting circuit performance with potentiometers, coupling loops, tuning slugs and trimmer condensers

Adjusting controls, setting switches, and reading quantitative indications on meters and gages

Adjusting microwave oscillators, waveguides and resonant cavities

Checking and adjusting power supplies

Connecting and disconnecting electrical, pneumatic and hydraulic fittings

Connecting and disconnecting microwave fittings

Manipulating test console front panel switches and controls and observing go-no-go indications

Operating mechanical test equipment and using hand tools

Performing numerical operations and using tables and graphs

Servicing and adjusting relays

Setting up (aligning and adjusting) and using standard and special signal generators

Using and calibrating simple meters to measure voltage, current, and resistance

Using synchroscopes and oscilloscopes

Additional categories of behavior and the specific tasks that require these behaviors are presented in Chapter 2 and Appendices A and B.

Trouble Shooting

The kinds of trouble-shooting behavior required for all five missiles studied, in order of the number of chassis requiring each kind of behavior, are as follows:

Diagnostic trouble shooting employing less complex test equipment and simple visual inspections

Diagnostic trouble shooting using complex test equipment

Trouble shooting using go-no-go test equipment

Trouble shooting using an unprogrammed test console

Description of the behavior in each of these categories is given in Chapter 2. The specific equipment on which trouble shooting is performed is listed in Chapter 2 and Appendix F.

Knowledge of Missile Operation

The elements of missile functioning that are common to at least four of the five missiles studied are the following:

AGC

Antennae, receiving

Antennae switches or antennae shields

Control surface transducers

Detectors

Error signal limiters

Error system rate correctors and amplifiers

Guidance switching and/or distribution circuits

Orientation sensing devices

Power sources

Power supply

Pulse amplifiers

Pulse time-sequence analyzers (coincidence and range sensing circuits)

Servo amplifiers and drivers

Terminal guidance and/or detonation control

Waveguides

Those elements common to fewer missiles and unique to a particular missile are presented in Chapter 2; this chapter also describes the circuitry involved in these elements.

Handling, Assembly and Servicing

The categories of behavior that are required for the performance of handling, assembly and servicing activities are similar for the five missiles studied; these categories are the following.

Assembling and disassembling missiles by hand and with hand tools

Attaching, securing, and detaching to lift, haul, and secure missiles and associated equipment

Checking and inspecting during missile transfer, assembly, and servicing

Connecting and disconnecting high pressure air and hydraulic lines during missile air and hydraulic servicing

Connecting and installing electrical wires, cables and parts during missile transfer, assembly, and servicing

Leveling, positioning, and measuring to align missile air surfaces and rockets

Locking-unlocking, assembling-disassembling, packing-unpacking and pressurizing-bleeding to remove and replace missiles and missile parts in containers

Lubricating, cleaning, and battery maintenance during missile assembly and servicing

Manually pushing, pulling, lifting, carrying, and manipulating to transport, position, and stow missiles, missile parts, and associated equipment

Operating motor vehicles and electrically powered equipment to lift, position, transport, and stow missile parts and associated equipment

Reading electrical and mechanical diagrams to determine missile assembly procedures

Setting valves and switches, and reading gages during missile air and hydraulic servicing

As indicated in Chapter 2, the nature of handling, assembly and servicing activities are such that the development of specific skills may best be a matter of on-the-job training.

Research Recommendations

Performing an analysis such as the one presented in this report brings into focus important problems for future research. Experience in guided missile personnel research has indicated that the research problems described below are of substantial importance for increased effectiveness in the utilization and training of personnel.

Specific Problems

1. Determination of the Theory Component of Training. The training of a guided missile technician, as indicated in this report, involves some training in electronic and other kinds of theory. However, the minimum extent of theory that permits maximally effective job performance has not been objectively determined. The determination of essential and non-essential theory or knowledge in different areas (electronic, hydraulic, propulsive, etc.) necessary for proficient job performance can contribute to (a) the establishment of training courses directly relevant to what a man must do in the field in his guided missile job, and (b) the reduction of theory requirements in a training program which might permit additional personnel to qualify for and successfully complete the course.

2. Development of Personnel Quality Control Procedures. Quality control of personnel is extremely important to maximize the reliability of guided missile field operations. This can be accomplished by the development of comprehensive, job-relevant proficiency measures which are administered in the course of a training program. Of particular importance in the light of the rapid engineering developments in the guided missile field is the construction of proficiency tests which predict an individual's ability to transfer his skills to new and modified equipment.

3. Development of Trouble-Shooting Training Techniques. Efficient trouble shooting is a crucial aspect in effective guided missile field operations. Detailed investigations, continuing the work presented in this report, should be made of the specific nature of the trouble-shooting procedures required for particular guided missiles. On the basis of such study, realistic and job-oriented trouble-shooting training and training evaluation procedures should be developed.

4. Evaluation of the Utility of Operation and Maintenance Manuals. Operation and maintenance manuals are tools of the job that must be designed for efficiency and ease of use. Appropriately designed manuals can reduce sources of job error and may permit less-highly trained individuals to utilize these manuals effectively.

5. Development of "Training Feedback" Procedures. Comprehensive procedures should be developed whereby sources of job error and changes in job design are continuously reported from field operations to training schools. Identification of error sources and the modification of training can contribute substantially to the improvement of missile reliability. By adequate reports of job design changes, training methods and course content can be kept up to date with changes in the field situation. With the development of such "training feedback" procedures, personnel leaving a school can be specifically prepared for their actual jobs and orientation time in the field can be substantially reduced.

6. Development and Evaluation of Training Aids. Concurrent with the development of guided missiles, elaborate guided missile operation and maintenance training aids and devices are being developed. Effective use of these aids and devices requires careful determination of their characteristics and utility before they are accepted as integral parts of a training program. Of importance in this connection, the evaluation of training manuals as effective training aids should be included.

7. Team Training and the Improvement of Team Operations. Detailed study should be made of operational guided missile team structure in order to determine the following: (a) the optimal composition of a guided missile team or unit in terms of the most efficient duty requirements of the team members; (b) the specification of techniques to evaluate effective team operation and to determine the sources of error in team functioning; (c) the kind of team training required to produce an effective guided missile team; and (d) the development of techniques for the analysis of team operation and the specification of basic principles of team functioning. Research activity accenting team training and the improvement of team operation is going on at the present time.

General Problems

8. Study of Job Analysis Methodology. The procedures employed for describing the behavior of an individual performing a task consist of various kinds of workable procedures that are not based on general principles or organized by a common methodology or a common universe of discourse. These procedures ordinarily fall under the general name of "job analysis." Research efforts need to be made in this area of job analysis methodology in an effort to (a) develop some general principles of describing behavior and to (b) develop procedures whereby the behavioral descriptions that are developed have a standardized meaning and utility to the users of these descriptions.

9. Learning and Training Differences at Different Levels of Aptitude. The selection of personnel at various aptitude levels needs to be supplemented by study of the relevant training factors required. A training situation involves input personnel of a specified aptitude level or range, training procedures, and some standard of performance. Little research has been done to study the

relationship between input aptitude level and accepted performance as a function of the intervening training variables. Research along these lines may eventually permit the specification of the "trainability" of various aptitude levels or the manner in which various aptitude levels should be trained to reach particular standards of performance.

APPENDIX A

MAJOR EQUIPMENTS ASSIGNED TO THE MISSILEMAN AND TO OVERLAPPING RATINGS

Terrier

Missileman duties can be concerned with the following major equipments:

Missile Components

- Receiver Package
- Intelligence Converter
- Missile Computer and Servo Amplifier
- Roll Stabilization System
- Programmer
- Pneumatic-Hydraulic System
- Sustainer
- Booster

Testing and Servicing Equipment

- BuOrd Functional Test Equipment, BOFTE (only preliminary and incomplete information available)
- Hydraulic Charging Unit
- Set-up Monitoring Panel
- Beam Simulator
- Guidance Analyzer
- Receiver Test Unit
- Monitoring Panel Test Unit
- Handling Equipment

Overlapping ratings can be concerned with the following major equipments:

Fire Control Radar Mk 25 Mod 6, 6A and 7, Stable Element Mk 6
Gun Director Mk 37 Mod 28
Computers Mk 84 and Mk 85
Launcher Mk 4 Mod 0
Missile Hoists and Conveyors (Ready Ring)
Standard Transporting and Handling Equipment

Regulus

In general the best available Regulus information has been somewhat incomplete and lacking in detail. Enough information, however, has been obtained so that an analysis of the tasks required can give what is judged to be a reasonable indication of missileman duties with respect to the Regulus missile. Most information is available for the Regulus Bi-Polar Guidance System; less information has been available on the Radio Command Guidance System or the Trounce Guidance System.

Missileman duties can be concerned with the following major equipments:

Bi-Polar Guidance--Missile Components

- Bi-Polar Guidance Set AN/DPW-3(XN-1)
- Flight Path Controller
- Terminal Guidance System

Bi-Polar Guidance--External Guidance System Components (These components may be the responsibility of a missileman assigned to submarine duty.)

- Bi-Polar Radio Beacon AN/BPN-1(XN-2)
- Bi-Polar Monitor Station

Radio Command Guidance--Missile Components

- Radio Command Receiver AN/ARW-59
- Audio Decoder KY-55/ARW
- Servo Amplifiers

Trounce--Missile Components

- Radar Transponder Beacon AN/APN-33
- Decoder
- Control Box (Command Translator)
- Terminal Guidance Systems

Missile Components Used with All Regulus Guidance Systems

- Electrical System
- Stabilization Hydraulic System

Overlapping ratings can be concerned with the following major equipments:

Bi-Polar Guidance (non-submarine personnel)

- Bi-Polar Radio Beacon AN/BPN-1(XN-2)
- Bi-Polar Monitor Station

Radio Command

- Control Console (Control Station)
- Audio Coder (modulator) KY-111/ARW (Control Station)
- Transmitter AN/ARW-55

Trounce

- Radar Course Direction Control P-1x
  - SV-1 Radar (modified)
  - Guidance Computer CP-98 (XN-1)/DPW
  - Nelco 1 Command Link

Equipment common to all Regulus Guidance Systems

- Firing Panel
- Autopilot (modified standard Navy--Sperry A-12 Autopilot)
- Pneumatic System
- Propulsion System (engine and JATO units)
- Wingfold Hydraulic System

Sparrow I

Missileman duties can be concerned with the following equipments:

Missile Components

- Guidance Receiver
- Guidance Amplifier
- Summing Amplifier
- Servo Amplifier
- Directional Free Gyro
- Rate Gyro
- Rectifier Units
- Junction Box
- Control Harness
- Sub Section
- Battery Unit
- Tail Section
- Tunnel Harness

Testing and Servicing Equipment (Interim Test Equipment)

- Microwave Test Console
- Video Control Console
- Video Test Console
- Servo Test Console

System Power Supply Test Console

Recorder Console

Hydraulic Console

Guidance Amplifier Test Console

Summing Amplifier Test Console

Servo Amplifier Console

Gyro Test Console

Sine Drive Assembly

Rate Gyro Unit Test Assembly

Pendulum Test Fixture

Rate Gyro Accelerometer Calibrator

Activated Battery Box Tester

Hydraulic Test Bench Assembly and Associated Fixtures and Testers

Guidance Receiver Oscilloscope Unit

R.F. and Video Console

Component Power Supply Test Rack

Instrument Stand

Missile Test Stand

Scorsby Table

Phase Shift and Tuning Unit (no information available)

Recorder, Guidance Receiver (no information available)

Recorder, Guidance, Summary and Servo Amplifier (no information available)

Pressure Test Bench (no information available)

Vibrator Assembly Tester (no information available)

Microphonics Tester (no information available)

Overlapping ratings can be concerned with the following major equipments:

Rocket Motor (JATO X11303)

Igniter
Radar Set AN/APQ-36 or AN/APQ-51
Control-Power Supply Group AN/APA-97
Warhead (Mk 6 Mod 0)
Fuze (T-3002)

Petrel

The available information on the Petrel missile indicated that specific trouble-shooting procedures might be specified in future technical manuals. Enough material was available, however, for adequate coverage of equipment check-out and for inferring trouble-shooting procedures.

Missileman duties can be concerned with the following major equipments:

Missile Components
- Radar Transmitter
- Radar Receiver
- Range Unit
- Yaw Unit
- Control Surface Actuators
- Antenna
- Antenna Stabilization System
- Power Supplies
- Missile Altimeter AN/DPN-5 (For this equipment a missileman can be concerned with testing and adjustment only.) (no information available)
- Missile Autopilot GM Mk 1 (For this equipment a missileman can be concerned with testing and adjustment only.)

External Guidance Equipment (This equipment is similar to particular missile components)

Control Monitor Group

Testing and Servicing Equipments

Missile Test Console

Handling Equipment

Overlapping ratings can be concerned with the following major equipments:

Torpedo Mk 13 or Mk 21

Missile Propulsion System (turbo-jet engine)

Missile Altimeter AN/DPN-5 (trouble-shooting and repair)

Missile Autopilot GM Mk 1 (trouble-shooting and repair)

Search Radar

Dove

Missileman duties can be concerned with the following major equipments:

Missile Components

Nose Fairing

Nose Assembly

Tail Assembly

Testing Equipment

Preflight Check-Out Console (only preliminary information available)

Overlapping ratings can be concerned with the following major equipments:

1000-pound general purpose bomb

Bomb Truck Mk 22 Mod 0

Bomb Sling Mk 21

Bomb Hoist Mk 8 Mod 0